DEVELOPMENT, AND MEASUREMENT OF S-BAND RECEIVING UNIT

A Thesis Submitted
In Partial Fulfilment of the Requirements
for the Degree of

MASTER OF TECHNOLOGY

by

M. SANKARAN

to the

DEPARTMENT OF ELECTRICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

APRIL, 1987

CERTIFICATE

This is to certify that the thesis entitled 'DEVELOPMENT, AND MEASUREMENT OF S-BAND RECEIVING UNIT' submitted by M. SANKARAN, for the partial fulfilment of the requirements for the award of M.Tech. degree, has been carried out under my supervision, and has not been submitted elsewhere for an award of a degree.

10th April, 1987.

(C. Das Gupta)
Professor
Department of Electrical Engineering
Indian Institute of Technology
Kanpur

ACKNOWLEDGEMENTS

I wish to express my heart-felt thanks to

- Dr. C. Das Gupta for the guidance and encouragement during the course of this work.
- My Director, DLRL, Hyderabad for providing me the opportunity to do this course.
- The Central Workshop staff for fabrication of reflector structure.
- My collegues Shri M.R. Kesheorey, LRDE and Shri P.K. Sharma, ADE for all help extended to me in completing the project.
- All my friends at IIT Kanpur, and DLRL Hyderabad for all the co-operation and encouragement extended to me during the course of my stay at IIT Kanpur.
- Mr. J.S. Rawat for his efficient and careful typing of the thesis.

\- M. Sankaran

ABSTRACT

Antenna is an important element of the communication systems in Radio bands. An antenna is a device used for radiating or receiving radio energy and acts as an interface between the free space and the communication equipment.

Work on the development, fabrication and measurement of S-band 6-element Dolph-chebyshev array built-in micro-strip form and a small parabolic cylinder reflector has been reported. Noise Figure Measurements carried out on a low noise amplifier is also reported.

The entire approach has been to develop an antenna array unit as an experimental model, the modified versions (with larger aperture area) can find its application for Direct reception of satellite signals. And also the revival of microwave measurement set-ups have been achieved.

TABLE OF CONTENTS

Page

CHAPTER 1

INTRODUCTION

1.1 GENERAL:

An antenna is a device used for radiating or receiving radio energy. It can also be thought of as a matching transformer or network which matches the impedance of the feeder to that of the free space. Antenna possess gain in certain directions by their capability to concentrate energy in that direction and suppressing or minimising in other directions.

A large variety of antennas have been developed to date. They range from simple monopoles to complex structures such as phased arrays. Antennas in general may be grouped in several different ways. One of these is to group them according to their applications [1].

A) According to Applications

1. Broad casting
2. Communications
3. Navigations, Telemetry
4. Radar
5. ECM (Electronic Counter Measure)
6. Radio Astronomy.

B) By Radiation characteristics

1. Omni directional
2. Unidirectional
3. Pencil beam
4. Circularly polarized
5. Fan beam
6. Null filling.

C) By Geometry

1. Unipole
2. Folded dipole
3. Paraboloidal Reflector
4. Corner Reflector
5. Rhombic
6. Helical, Spiral, Horn, etc.

D) General Class

1. Electrically small
2. Travelling wave
3. Resonant
4. Frequency Independent
5. Array
6. Reflector etc.

1.2 ANTENNA:

Antennas currently being used in microwave radio relay links - terrestrial line of sight, troposcatter or satellite are derived from the paraboloid of revolution. There are two types viz., the single reflector and double reflector types. Antenna belonging to the single reflector types are the parabolic, shell and horn reflector antennas while the cassegrain antennas belong to double reflector type of antennas.

The most popular type of communication antenna for radio relay links is the parabolic antenna. It consists of a parabolic dish, at the focus of which is placed a feed or primary reflector. The energy from the feeder is guided by the feed or the primary radiator on to the parabolic reflector. Here it is converted to a plane wave after reflection from the surface as also it gets collimated. The reflector focuses the radio energy in much the same manner as light is focused by a mirror. The performance of a parabolic antenna is highly dependent on the feed design and on the measures adopted to control the illumination of the paraboloid surface.

1.3 ARRAYS:

The term array as applied to antennas, means an assembly of radiating elements in an electrical and

geometrical arrangement of such nature, that the radiation from the elements 'adds up' to give a maximum field intensity in a particular direction or directions and cancels or very nearly cancels in others. The long wire antenna can be regarded as an assembly of elemental dipoles in a geometric configuration that provides directivity and gain. But generally the term ARRAY, is usually reserved for arrangements in which the individual radiators are separate rather than part of a continuous radiator.

The radiation pattern of an array in free space depends on four factors.

1. The relative position of the individual radiators with respect to each other.
2. The relative phases of the currents or fields in them.
3. The relative magnitudes of the individual radiator currents or fields.
4. The patterns of the individual radiator.

Dolph-Chebyshev array developed in microstrip form with six-monopole radiators is used as a feeder for a parabolic cylinder reflector.

1.4 MICROSTRIP TRANSMISSION LINE:

In recent years, much effort has been given to miniaturising microwave circuits by the use of microstrip transmission line. A diagrammatic cross-sectional view of this transmission medium is shown in Fig. 1.1. Essentially, it consists of a dielectric substrate, such as RT/Duroid, alumina, with a chosen thickness H. Distributed or lumped microwave components are fabricated by producing a conductor pattern on one face, and a ground plane on the other. Conductors of closely controlled conductivity and dimensions are best obtained by evaporation, subsequent electroplating and final high-resolution photolithography.

Microstrip is essentially an open structure, having the microwave field shared between the dielectric substrate and air. This means that the mode is not TEM, and makes the wavelength a complicated function of the relative permittivity ϵ_r of the substrate, the geometry of the line W/H, and the operating frequency. But the bulk of the energy is transmitted along microstrip with a field distribution which quite closely resembles TEM and it is usually referred to as 'Quasi TEM' [2]. Simple approaches to the Quasi-TEM mode calculations combined with frequency dependent expressions yield quite acceptable design accuracy within 1 percent, for many applications.

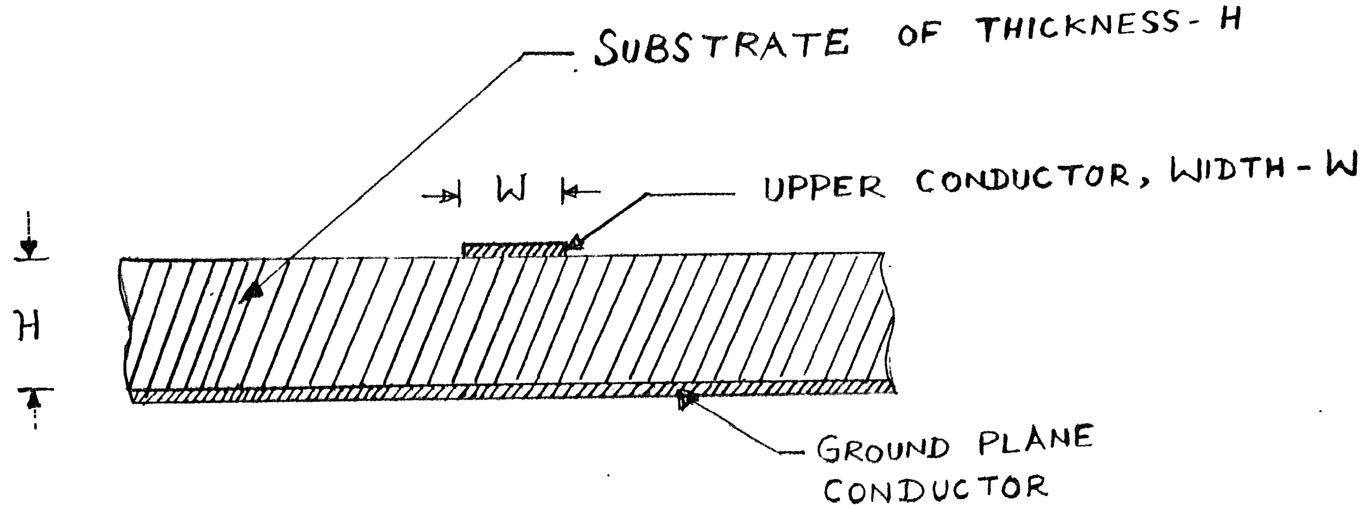


Fig. 1.1: Cross-sectional view of Microstrip Transmission line

Microwave integrated circuits using microstrip can be designed at frequencies ranging from a few GHz or even lower, upto many tens of GHz. Feed lines, matching networks, and branch line couplers can be fabricated simultaneously on the board in microstrip form for the specific operating frequency and application.

1.5 AIM OF THE PROJECT:

The main objective of the project is the development, fabrication and testing of S-band antenna array unit. The antenna array unit consists of

a) Feeder - S-band design of Dolph ChebyShev array built in microstrip form on a RT/Duroid substrate with six monopole radiators.

b) Reflector - A parabolic cylinder reflector made of aluminium sheet with the aperture area of 0.64 square meter.

Bulk of the work is centered around the development and fabrication of the antenna array unit. VSWR (Return loss) measurement on the antenna is carried out using a 'Microwave Network Analyzer' and Noise Figure of the front end amplifier is measured using 340B Noise Figure Meter.

During the time of measurement, the need for a Modern Microwave Measurement set up, is felt to achieve better performance evaluation of devices and systems. Hence a brief description on Automated Measurement facility and the performance evaluation carried out on a Mixer-preamplifier is also included in this thesis report.

CHAPTER 2

DEVELOPMENT OF S-BAND ANTENNA ARRAY UNIT

2.1 GENERAL:

In any communication system that transmits or receives electromagnetic energy into or from the free space, an ANTENNA is perhaps the single most important component. Its functions is to couple energy from a transmission line into the free space and vice versa. In broad sense an antenna is an impedance matching component-effectively, it matches the impedance of the transmitter or receiver circuitry to that of the medium used, so as to maximize the transfer of power.

The basic microwave antenna has two components

1. a small feed, and
2. a large reflecting surface.

The advantage of reflector type antenna lies in the ease with which a high gain can be achieved. The development and fabrication of the S-band antenna array unit is split into two parts.

1. Reflector - Parabolic cyliner
2. Feeder - Dolph-Chebyshev array

2.2 DEVELOPMENT OF REFLECTOR:

2.2.1 Reflector Antennas:

The reflectors are derived from the conic sections. The basic conic sections are circle, ellipse, parabola and hyperbola. The first reflector antenna was born in 1888 in the laboratory of Heinrich Hertz [3]. Hertz used a cylindrical parabolic reflector of zinc with a spark gap excited dipole placed on the focus line. Reflector antenna which now dominate the field of microwave antennas, thus have their origin in the days of Hertz. Famous Indian Physicist Sri J. Chunder Bose's lecture demonstration in 1897 at the Royal Institution in London was another landmark in the development of reflector antennas. There were many developments during and after the second wold war. The world's largest Reflector antenna is the 'Arecibo antenna' with a mirror in the form of 70 degree cap of a sphere whose radius is 870 feet and the resulting aperture diameter is 1000 feet.

2.2.2 Parabolic Reflectors:

A plane sheet may be formed into the shape of a parabolic curve and used with a driven radiator situated at its focus, to provide a highly directive antenna system. If

the parabolic reflector is sufficiently large so that the distance to the focal point is a number of wavelengths, optical conditions are approached and the wave across the mouth of the reflector is a plane wave. However, if the reflector is of the same order of dimensions as the operating wavelength, or less, the driven radiator is appreciably coupled to the reflecting sheet and, minor lobes occur in the pattern. With an aperture (open end of the parabola) of the order of 10 to 20 wavelengths, sizes that may be practical for microwave work, a beam width of approximately 5 degree may be achieved.

The most desirable focal length of the parabola is that which places the radiator along the plane of the mouth; this length is equal to one half the mouth radius. At other focal distances interference fields deform the pattern or cancel a sizable portion of the radiation.

If a beam of parallel rays is incident on a suitably curved reflector, the rays will be brought to focus at a point, as shown in Fig. 2.1. Similarly, if a point source of radiation is placed at this focal point, the rays from it will be reflected in such a way that they emerge as a parallel beam. Rays that are parallel are said to be

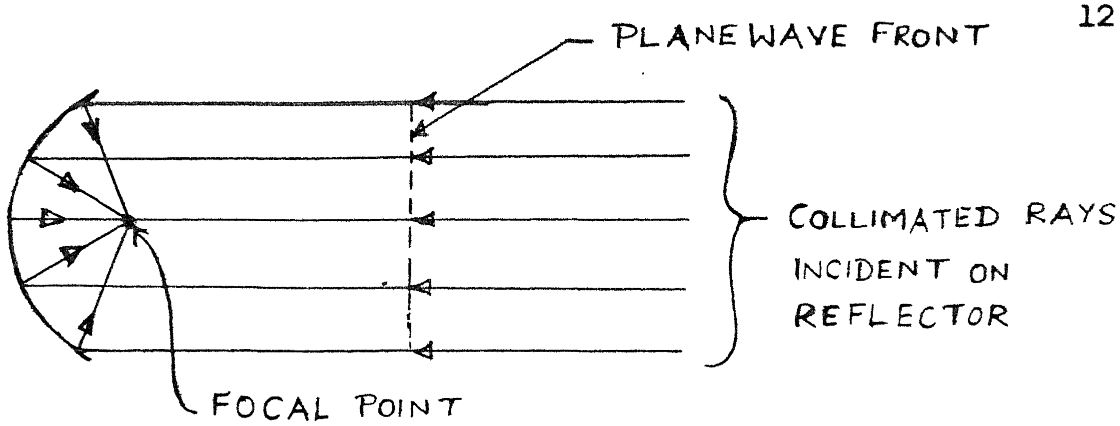


Fig. 2.1: Focussing and Collimation

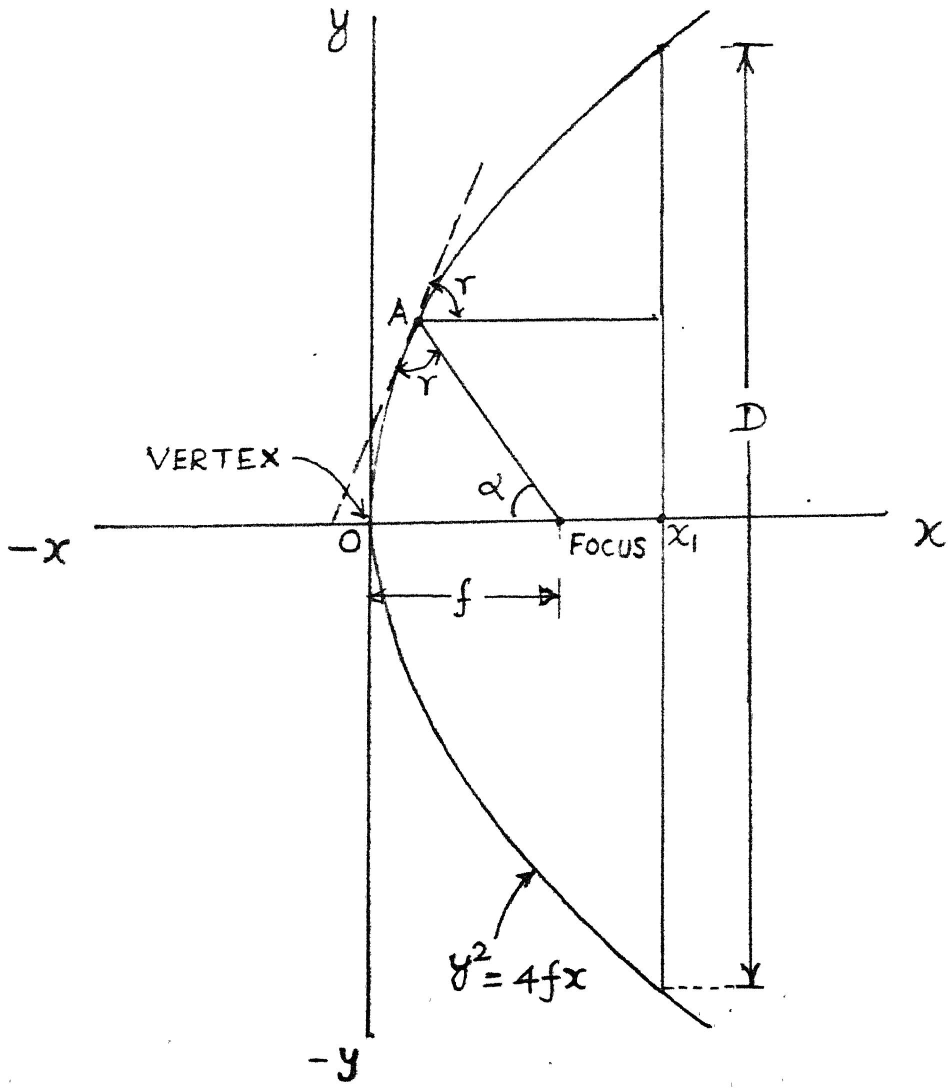


Fig. 2.2: Geometry of Parabolic Reflection

collimated. In a sense, they are focussed 'at infinity'. It can be shown that this collimation occurs if the shape of the reflector is parabolic. The giant search light is a familiar example of this type of reflector.

The gain of a uniformly illuminated aperture type antenna without losses is expressed by

$$G = \frac{4\pi A}{\lambda^2} \tag{2.1}$$

Where A is the aperture area and λ is the wavelength. The value of gain obtained from this expression normally represents an upper limit which can be realized with practical structures.

2.2.3 Geometry of Parabola:

The geometry of parabola [4] can be expressed in terms of cartesian (rectangular) co-ordinates as shown in Fig. 2.2. The horizontal axis, labeled x, lies along the axis of the parabola, which is a line of symmetry. The point at which this axis intersects the parabolic curve is called the VERTEX. The second co-ordinate axis, labeled y, passes through vertex. At a certain distance 'f' from the vertex, on the parabolic axis, is a point labeled focus. The equation of the parabolic curve, in terms of these co-ordinates and the parameter 'f' is

$$y^2 = 4fx \qquad (2.2)$$

The focal point, or focus, at distance 'f' from the vertex, is the point at which incoming collimated rays will converge or from which the diverging rays of a point source will be collimated. Practical parabolic reflectors are of finite depth; they terminate, or are 'cut-off' at some finite value of x, denoted by x_1 in Fig. 2.2. The open mouth of the parabola is known as the APERTURE. The aperture dimension is labeled D. The ratio of focal length to the aperture size f/D - commonly referred to as the 'f over D ratio' is an important characteristic of a parabolic reflector. It is determined by the depth of the reflector, x_1, in relation to focal length f. Table 1 shows typical values of Antenna gain vs. f/D ratio for 10 dB illumination [5].

Table 1: Antenna Gain vs. f/D (10 dB illumination)

f/D	0.35	0.50	0.75
GAIN	34.8	35.6	35.6

A parabola whose depth is exactly equal to the focal length (x_1=f) will have a value of D equal to 4f, and hence for this parabola the f/D ratio is 0.25. It is generally inadvisable to make a parabolic reflector deeper than the focal length, and ordinarily the f/D ratio will range from 0.25 to 0.5.

By simple geometric analysis it can be shown that the length of the path (focus to A and A to the aperture plane - ray) is equal to f+x_1, for all values of the angle α. The result is obvious for the special case of α=0. This means that the phases of all waves thus arriving at the aperture plane are the same. Thus a wavefront, a surface of constant phase is created in the aperture plane. Hence the rays are parallel to the axis, since rays are always perpendicular to a wavefront.

2.2.4 Parabolic Cylinder:

A parabola is a plane curve, that is it is two dimensional. A reflector, being a curved surface, is a three dimensional object. There are two types of surfaces-paraboloid and parabolic cylinder that produce parabolic reflection. The parabolic cylinder is formed translating the parabola of Fig. 2.2 in the direction of the z-axis, that

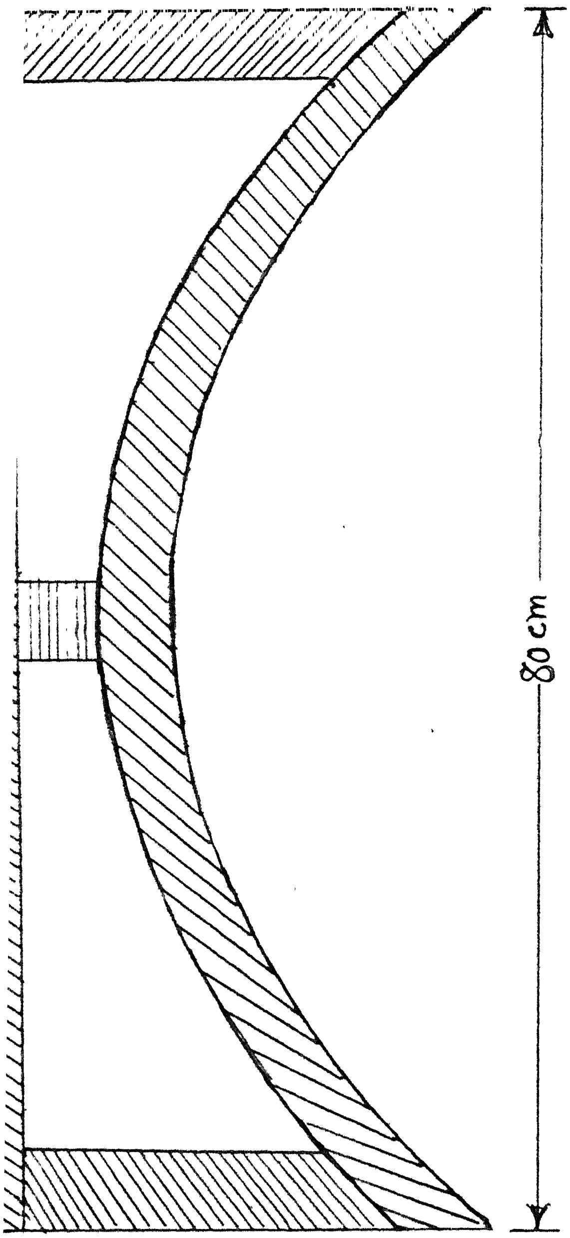
is, by moving it sideways. The intersections of all planes parallel to the xy plane with the parabolic cylinder are parabolas like the one shown in Fig. 2.2. The intersections of all planes parallel to the zx-plane with the parabolic cylinder are straight lines. If the cylindrical surface has a finite dimension in the z direction, the reflector as viewed from a distance on the x-axis will appear rectangular,(i.e.) it has a rectangular aperture. The parabolic cylinder has a focal line, rather than a focal point, and a vertex line.

2.2.5 Construction of the Reflector:

Parabolic-cylinder reflectors are easy to construct upto about 10 feet in diameter by using template techniques. The smaller dishes are generally made of aluminium. They are formed by spinning or stretching on a solid form or cutouts made of wood, using a parabolic template to check the shape. The template is in the form of a parabolic curve conforming to the equation

$$y^2 = 4fx$$

for the desired value of f, the focal length. For a parabolic cylinder, it is provided with a translational axis on which it can be moved along a line parallel to the desired focal line.



<u>Table 2</u>

$y^2 = 4fx$
$f = 20$ cm

x	y
1	8.95
3	15.50
5	20.00
7	23.70
9	26.83
11	29.70
13	32.25
15	34.64
17	36.88
19	38.99
20	40.00

Fig. 2.3: Wooden Template (Support)

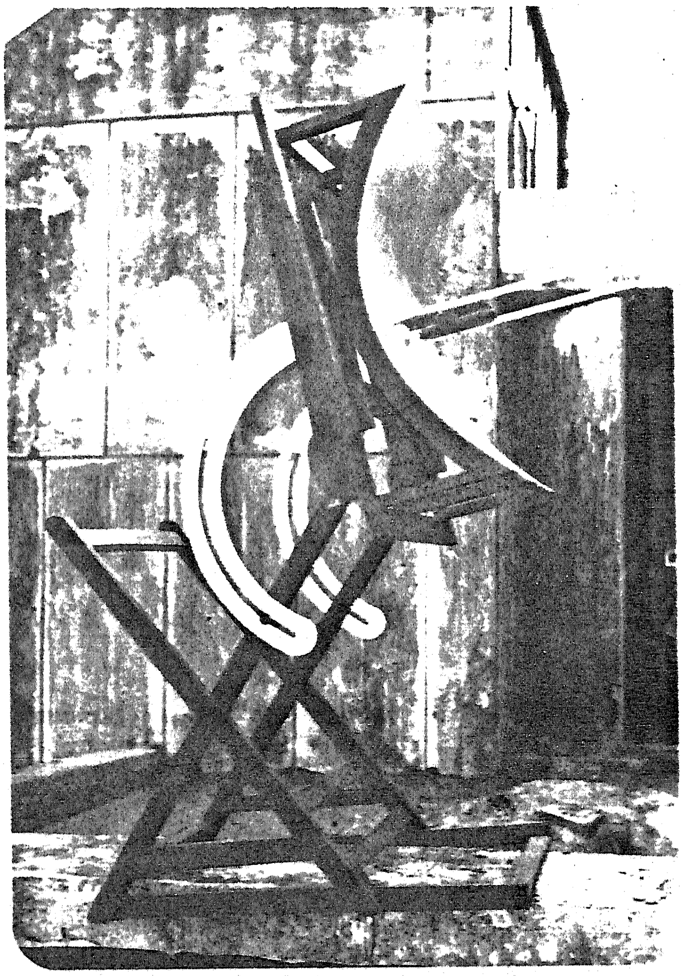


Fig. 2.4: ANTENNA - STRUCTURE

As an experimental model for feeder, a small parabolic cylinder reflector has been constructed. With the focal length of 20 cms, the template is made out of wood to form the basic support as shown in Fig. 2.3. Table 2 shows the (x,y) co-ordinates which forms the parabolic curve. Further provision is made to adjust the elevation of the reflector and the focal length of the feeder as shown in Fig. 2.4.

2.3 DEVELOPMENT OF DOLPH CHEBYSHEV ARRAY:

2.3.1 Illumination Taper:

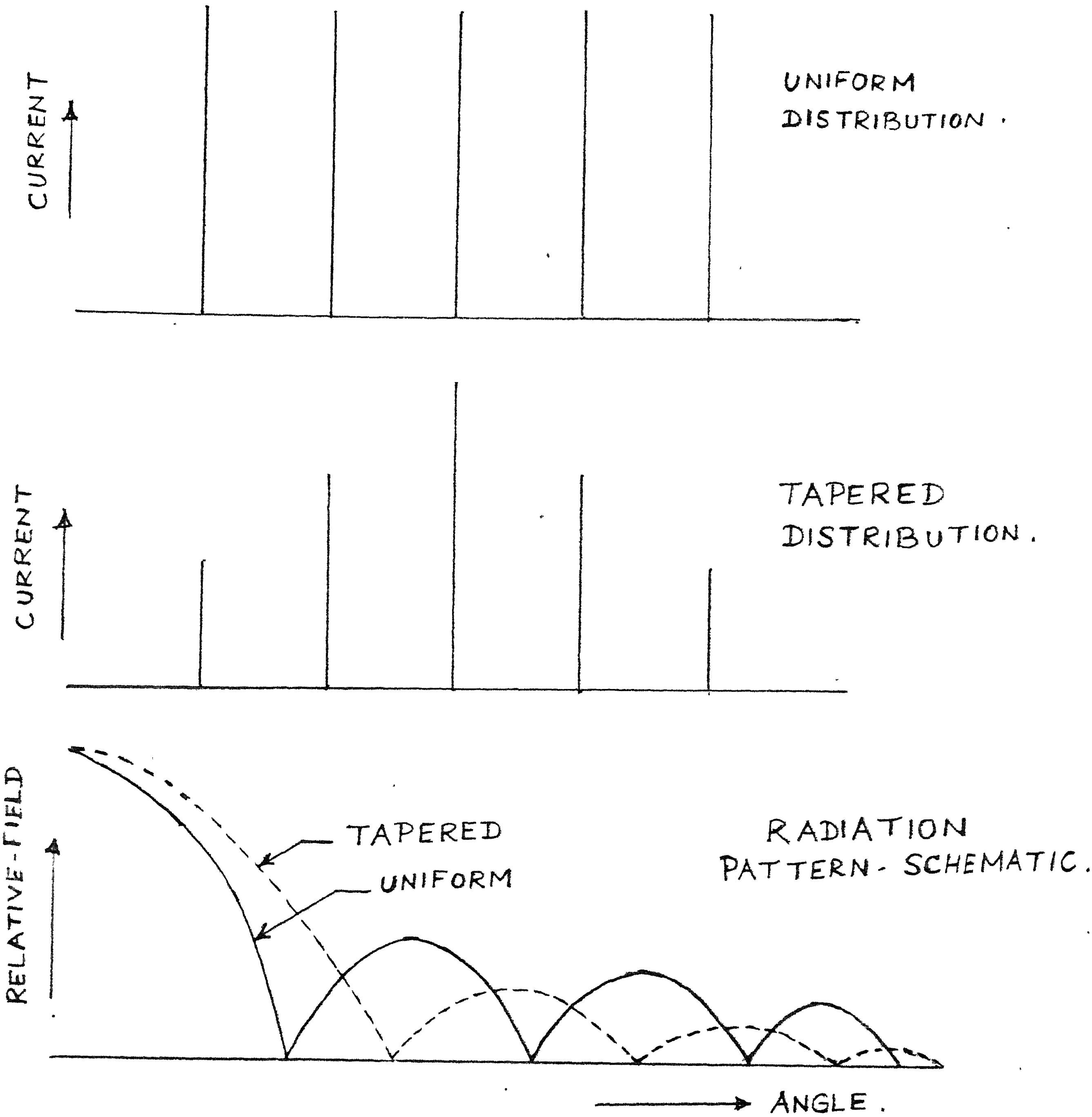
Ideally the feed should have a pattern of such nature that it radiates towards the reflector so as to illuminate the entire surface with little or no energy radiated in other directions. Such an ideal pattern is ofcourse unattainable, but some types of feed radiators are much better than others. Most commonly used feed is a horn, for parabolic reflectors. The radiation from the feed is called the illumination of the reflector. The variation of the intensity of radiation over the aperture is called the illumination taper.

A uniform distribution (when the amplitude of current is the same in each element of an array) leads to large side-lobes. The basic technique for reducing side lobes is simple.

Instead of uniform current distribution, one must have a tapered distribution, that is, the amplitudes of current must decrease towards both edges of an array. An example is shown in Fig. 2.5. The radiation pattern exhibits a wider main beam and lower side lobes when the current distribution is tapered.

2.3.2 Dolph Chebyshev Distribution:

Directional antenna patterns are usually characterised by minor lobes in addition to the main lobes. Although the principal advantage of a directional antenna may be the gain that it provides in the desired direction, some times it is almost equally important to minimize radiation towards or reception from an undesired direction. Because of the importance of the side lobe level, the subject has been studied very thoroughly, and a technique called TAPERING to reduce the sidelobes has been developed. The term tapering refers to non-uniformity of element strengths (e.g. dipole currents) in a linear array. It has been found that minor lobes are reduced in amplitude if the center elements of the array radiate more strongly than the end elements, the strengths being tapered from center to end according to some prescription.



. 2.5: Current Distribution and Radiation Pattern of a
Five Element Array.

One of the most useful prescription is the Dolph-Chebyshev distribution. The theory and procedure worked out by C.L. Dolph [6] are based on the use of mathematical functions called Chebyshev polynomials. Dolph's approach to the problem recognizes that a reduction of sidelobe level cannot be accomplished without sacrifice of antenna performance in some other respects. The other performance parameters affected are the beam width and the gain (directivity), but the primary one is the beamwidth.

A sample of tabulated values of Dolph-Chebyshev distribution is shown in Table 3.

Table 3

Element number	Relative current
1 and 8	0.26
2 and 7	0.52
3 and 6	0.81
4 and 5	1.00

The current distribution is symmetrical about the center of the array; hence the elements can be grouped in pairs as

shown. The current values are normalized to the value of the unity at the center of the antenna, and the end element currents are only 26% of the center elements current for 30 dB sidelobe level.

Practically it is common to design high gain narrow beam antennae for side lobe levels of 20 to 30 dB in the VHF and UHF bands. A 20 dB level is considered good, and 30 dB is excellent, but 40 dB is considered very difficult to achieve.

2.3.3 Dolph-Chebyshev Array:

Dolph-Chebyshev arrays offer the advantages of very low, constant sidelobe levels along with narrow beamwidth. Theoretical calculations are readily available for systems with side lobe levels as low as -45 dB with as many as 24 elements [5,6]. A six element Dolph-Chebyshev antenna array system with -30 dB theoretical sidelobe levels has been built in microstrip form on RT/duroid substrate. The S-band design uses simple monopole radiators - rigid length of rods with specified length and length to diameter ratio that results in a proper impedance matching of 50 Ω with the distribution system.

2.3.4 Design of Dolph-Chebyshev Array:

The design procedure involves the distribution of energy (current) by means of branchline couplers. The simplified design procedure discussed here consists of an even number of equally spaced elements with all currents in phase and symmetrically distributed about the centre of the array.

Having chosen a number of elements equal to 2N, the desired sidelobe ratio 'r' is then chosen, where

$$r = \frac{\text{main lobe (maximum) level}}{\text{Side lobe level}}$$

A parameter x_o, which is related to the sidelobe ratio can be determined from

$$x_o = \cosh \left[\frac{1}{2N-1} \cosh^{-1} r\right) \qquad (2.3)$$

The element excitation values are readily determined once the sidelobe ratio r has been chosen and the parameter x_o calculated. A separate set of relationships is necessary for each array consisting of 2N elements. The expressions for the relative current values of 6 element array starting from the outer radiator pair are as follows [6,7].

$$I_1 = x_o^{5}$$

$$I_2 = 5I_1 - 5x_o^{3} \qquad (2.4)$$

$$I_3 = 3I_2 - 5I_1 \pm 5x_o$$

The spacing between the radiators, can be adjusted to get the desired half power beamwidth which can be expressed as [5] follows.

$$\text{Sin}\ \phi_{HP} = \frac{\lambda}{\pi d} \cos^{-1}\left[\frac{1}{x_o} \cosh\left(\frac{1}{2N-1}\cosh^{-1}\frac{r}{\sqrt{2}}\right)\right] \qquad (2.5)$$

where;

ϕ_{HP} is the angle at which the main lobe has fallen to half power (3dB down)

d - element spacing

λ - wavelength correspond to frequency of operation

r - side lobe ratio

and x_o - the element parameter.

The distance between the radiators must remain in the vicinity of $\lambda/2$.

Once the current distribution is known and the effects of mutual coupling are accounted for, the coupling values of

the branch line couplers are calculated. For example, a six element Dolph-chebyshev array system with a theoretical sidelobe level of -30 dB and half power beamwidth of 22 degrees would require 3,5 and 12.3 dB couplers [7]. Because of the practical difficulty in realising the width of the high impedance line of the order of 0.1 mm for 12.3 dB coupler, an alternate approach has been made by means of 9 dB and 4 dB couplers. The 4 dB coupler by passed the extra amount of power from the outer radiators in order to satisfy the power distribution according to Dolph-chebyshev distribution. The layout is symmetrical with respect to 5 dB coupler.

The couplers are properly terminated and the radiators of 2 mm in diameter and 22 mm in length are used. The length and length to diameter of the radiator is estimated using the following relation,

$$Z_i = 20\,(K\ell)^2 - j120(K\ell)^{-1}\,(\log_n \frac{2\ell}{a} - 1) \qquad (2.6)$$

where,

Z_i = input impedance in ohms

2ℓ = length of the radiator

a = radius of the radiator

$(K\ell)$ = $2\pi(\ell/\lambda)$ = electrical length corresponding to ℓ measured in radians.

The functions $R(K\ell)$ and $X(K\ell)$ vs. $(K\ell)$ are available in the form of graph/table [5]. The impedance of the radiator is compared with the input impedance of the distribution system.

2.3.5 Design of Microstrip, Branch line Couplers:

The main design problem is to evaluate the physical widths and lengths of the microstrip lines. The width of a microstrip line is principally a function of its characteristic impedance and the thickness of the substrate. The physical length depends upon the wavelength (frequency), width and the substrate permittivity. Explicit iterative formulae and techniques are available [2] for the accurate design problems.

The following formulae obtained by rational function approximation give an accuracy of $\pm$ 0.25% for $0 \leq \frac{W}{H} \leq 10$, which is the range of importance for most of the engineering applications [8].

$$Z = \frac{Z_o}{(\epsilon_{eff})^{1/2}} \qquad (2.7)$$

$$\epsilon_{eff} = \left(\frac{\lambda_o}{\lambda}\right)^2 \quad \text{(i.e.)} \quad \lambda = \frac{\lambda_o}{(\epsilon_{eff})^{1/2}} \qquad (2.8)$$

where Z_o and λ_o are the characteristic impedance and wavelength with reference to an Air line. ϵ_{eff} is an

important microstrip parameter termed the Effective Microstrip permittivity and Z and λ are the strip impedance and wavelength.

The effective dielectric constant changes with the radio of strip width W to the substrate thickness H.

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r - 1}{2(1+\frac{10H}{W})^{1/2}} \tag{2.9}$$

where ϵ_r is the substrate dielectric constant. By graphical synthesis [2], $\epsilon_{eff} = 1+q(\epsilon_r-1)$

(2.10)

where q is the microstrip filling fraction.

$$Z_o = 60 \ln\left(\frac{8H}{W} + \frac{W}{4H}\right), \quad \frac{W}{H} \leq 1 \tag{2.11}$$

$$Z_o = \frac{120\pi}{(W/H)+2.42-0.44(\frac{H}{W})+1-(\frac{H}{W})^6}, \quad \frac{W}{H} \geq 1 \tag{2.12}$$

The impedance can be found when $\frac{W}{H}$ is known. But most of the design problems require the opposite (i.e.) given the impedance, find W/H where H is also known for the substrate chosen.

Fig. 2.6 shows the schematic of a two branch coupler . The characteristic impedance of the external lines connecting to the coupler (Z_o air = 50) and the value of coupling are known. Branch line couplers are directional couplers consisting of two parallel transmission lines coupled through a number of branch lines. (Two branch couplers are considered here). The lengths of branch lines and their spacings are all one quarter guide-wavelength at the frequency of operation. From the Design Curves [10] available, the series and shunt arm impedances of the branch line couplers are found for different values of coupling. Knowing the different Z_o values, and $_{eff}$ of the substrate, λ, Z and W are calculated for the midband frequency of 3 GHz using the formulae given before.

RT/duroid (5870) substrate with dielectric constant of 2.33 with standard thickness of 1/16 inch, is chosen for fabrication. Fig. 2.7 and Fig. 2.8 shows the final layout of the feeder and the fabricated feeder respectively.

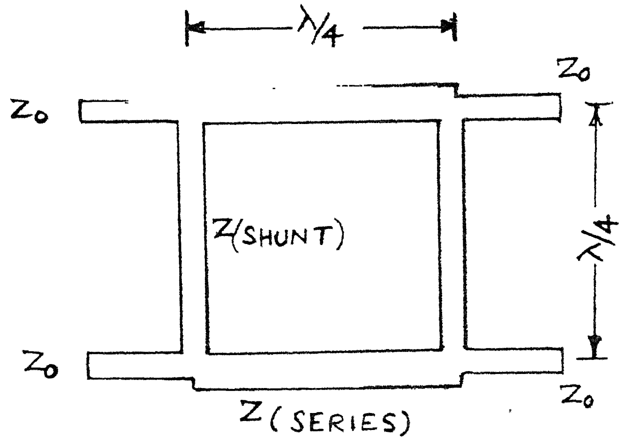


Fig. 2.6: Branch Line Coupler - Schematic

SERIES AND SHUNT IMPEDANCES
VS COUPLING
(FROM DESIGN CURVES [10])

COUPLING (dB)	Z series (ohms).	Z shunt (ohms)
3	35.4	50.0
4	39.0	61.5
5	43.0	73.5
9	47.0	133.0

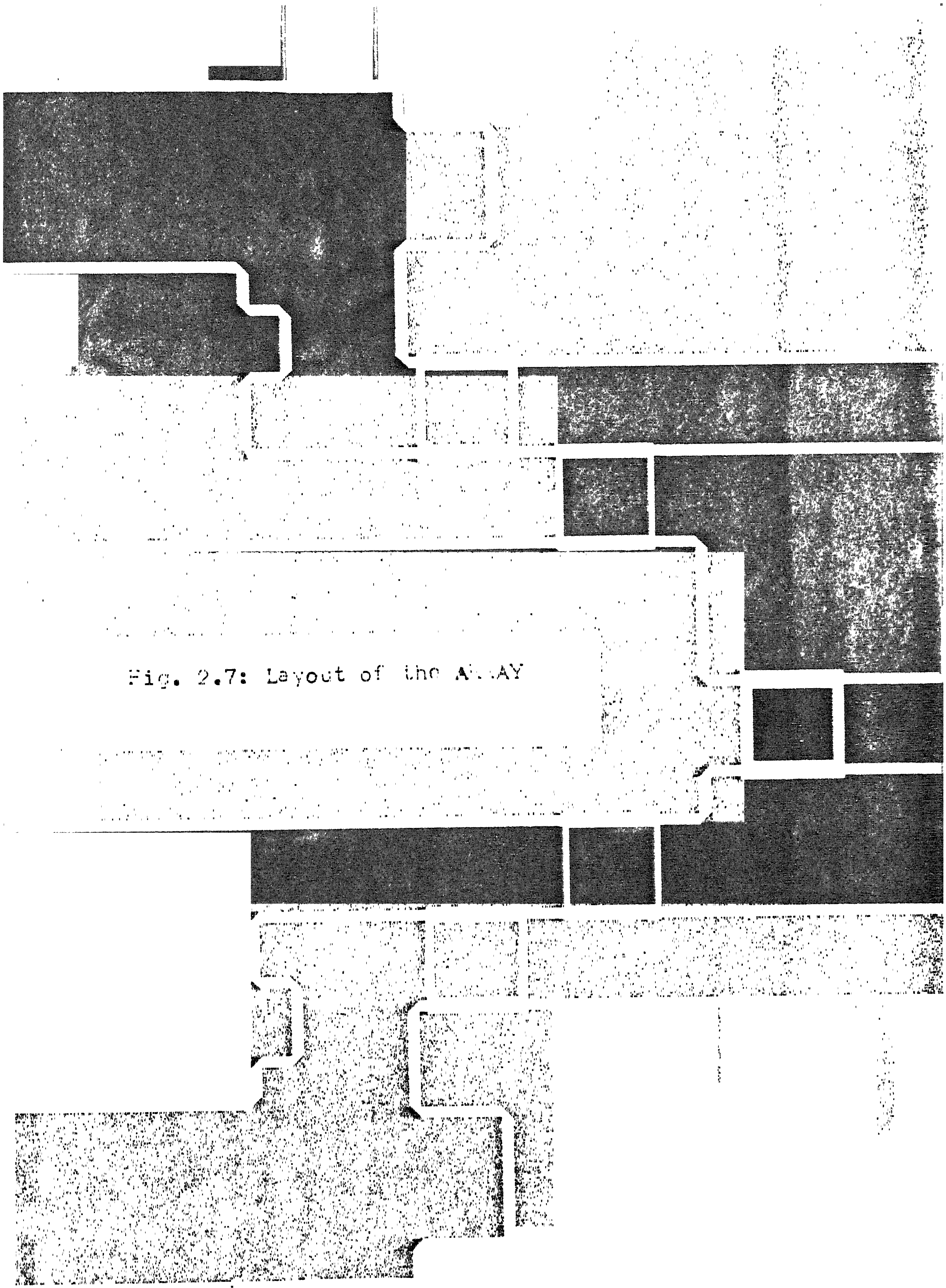


Fig. 2.7: Layout of the ARRAY

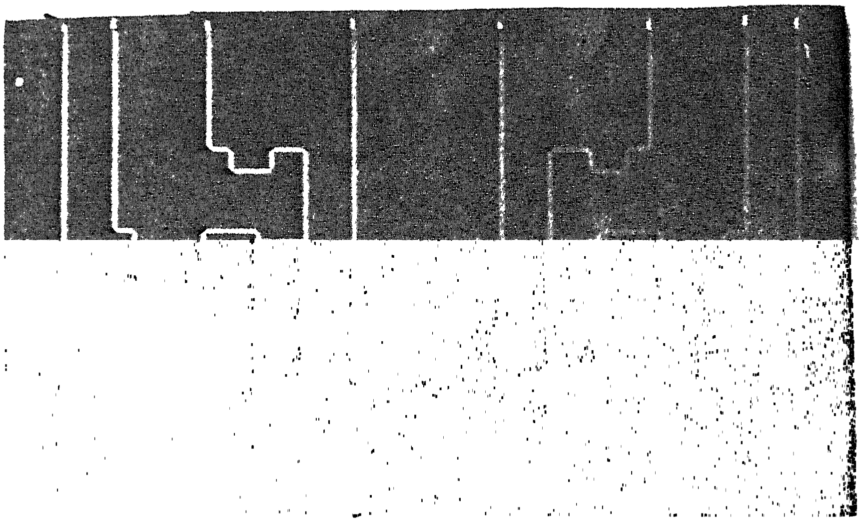


Fig. 2.8: Fabricated Feeder

CHAPTER 3

SYSTEM PARAMETERS

3.1 GENERAL:

Knowledge of different parameters are essential to evaluate the performance of a system. The parameters which describe the electrical performance of the antenna are described briefly. Noise Figure is the parameter of a receiver/front end amplifier, which characterises the ability of the receiver to detect the weakest signal discriminating noise. The Noise Figure parameter is also described briefly.

3.2 ANTENNA PARAMETERS:

Frequency Band: Frequency band refers to the operating frequency range. It is generally possible to tune the antennas for slightly different frequency ranges while retaining the same electrical performance. These days two antennas working, one for transmission and one for receive is not generally used.

Voltage Standing Wave Ratio (VSWR): VSWR is a measure of the reflection from the antenna when connected to a system of defined impedance level. VSWR is the most important parameter for any microwave device. If the matching of the

antenna is perfect and there are no reflections, then ideally VSWR is unity. Antennas in different frequency bands and of different types exhibit VSWR's ranging from 1.05 to 2.

Reflections from a mismatch are undesirable for a number of reasons. The obvious one is that under a mismatch only a fraction $1 - |K|^2$ of energy on the line is delivered to the load, the remainder being wasted. K is the reflection coefficient which is defined in terms of VSWR as follows

$$|K| = \frac{VSWR - 1}{VSWR + 1} \tag{3.1}$$

Return loss is the ratio of power in the direction of the antenna from the equipment (usually called forward power) to the power reflected from the antenna back into the equipment (reflected power). The ratio of forward and reflected powers expressed in dB, is the Return Loss. Return Loss can also be expressed in terms of reflection coefficient as follows,

$$\text{Return Loss in dB} = 20 \log_{10} \left|\frac{1}{K}\right| \tag{3.2}$$

In general the mismatch of impedance is expressed in terms of VSWR for antennas and interms of Return Loss for

microwave devices. Table 3 gives the conversion table from VSWR to Return Loss.

GAIN : Gain is a measure of the ability of the antenna to direct the power delivered to the input into radiation in a particular direction. It is measured at the peak radiation intensity. The gain is specified generally in three ways. It is important to note the subtle difference. Gain is expressed in dB.

Directive gain is the computed gain from the radiation pattern of the antenna. This does not take into account the efficiency of the antenna and therefore tends to boost the gain value.

Isotropic gain is the most commonly specified gain and usable for link computations. This refers to the gain obtainable in dB as referred to an isotropic radiator. Thus G = 10 dBi refers to the gain of an antenna with respect to an isotropic radiator as 10 dB. An isotropic radiator is a hypothetical radiator which radiates equally in all directions. Such an antenna has zero directivity. Physically it is not possible to realise an isotropic radiator, but used as a convenient reference antenna.

Table 4: Conversion Table
VSWR to Return Loss

VSWR - Voltage Standing Wave Ratio

K - Reflection Coefficient

VSWR (Ratio)	Return Loss in dB $= 20 \log_{10} \left\|\frac{1}{K}\right\|$
1.05	32.26
1.1	26.45
1.2	20.83
1.3	17.70
1.4	15.56
1.5	14.00
1.6	12.74
1.7	11.73
1.8	11.00
1.9	10.16
2.0	9.54
3.0	6.00
4.0	4.44
5.0	3.50
∞	0

The third way of specifying gain is to refer the same with respect to a half wave dipole. The gain of a half wave dipole is 2.14 dB with respect to an isotropic radiator, thus the gain with respect to a half wave dipole, it should be increased by 2.14 dB to get the isotropic gain in dBi.

Half Power Beamwidth: This is measured in degrees on either side of the main lobe where the power falls by half (3 dB). The plane containing the direction of the main lobe is considered. The full angle between the two directions in that plane about the maximum in which the radiation intensity is one half (3 dB below) the maximum value of the lobe is called the 3 dB beamwidth or half power beamwidth or simply the beamwidth of the antenna. The beamwidth characterises the directive properties of an antenna; smaller the beamwidth, sharper or narrower the beam. Fig. 3.1 shows the 3 dB beamwidth of an antenna.

Side-lobe Suppression: It is a measure of the first side-lobe level relative to the main lobe of an antenna expressed in decibels (dB). A radiation pattern plot of the unit as a receiving antenna gives the side lobe level directly in decibles taking the mainlobe maximum as a zero dB reference level.

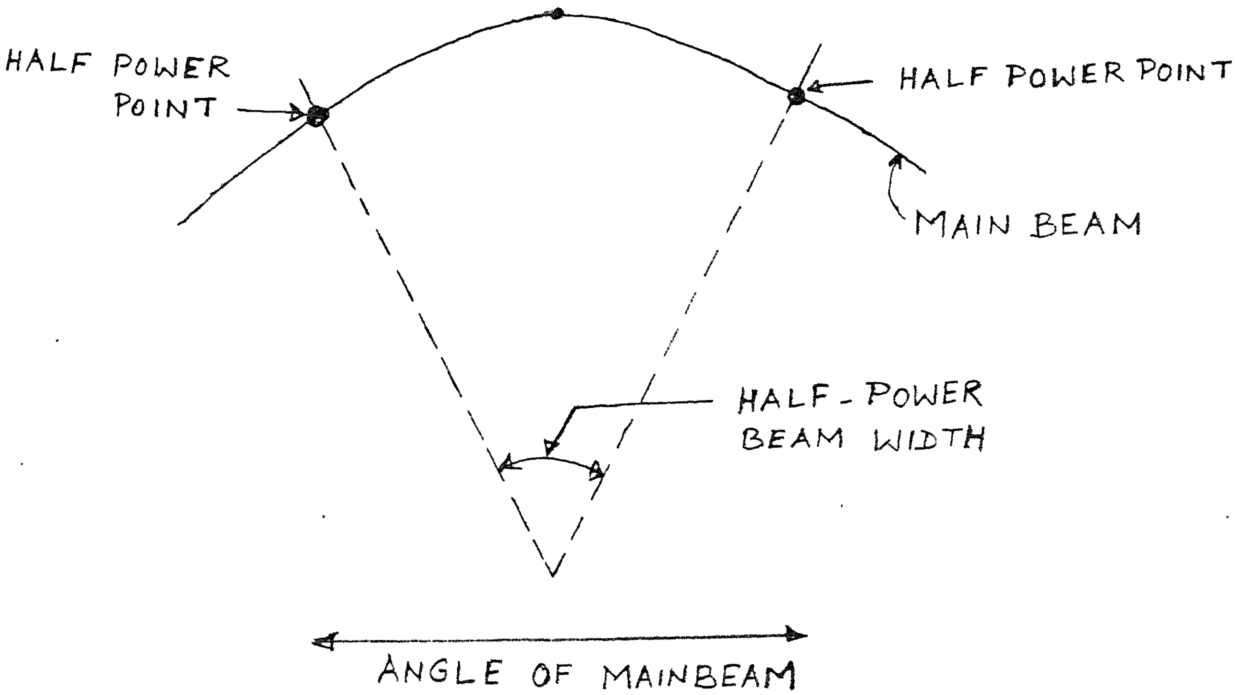
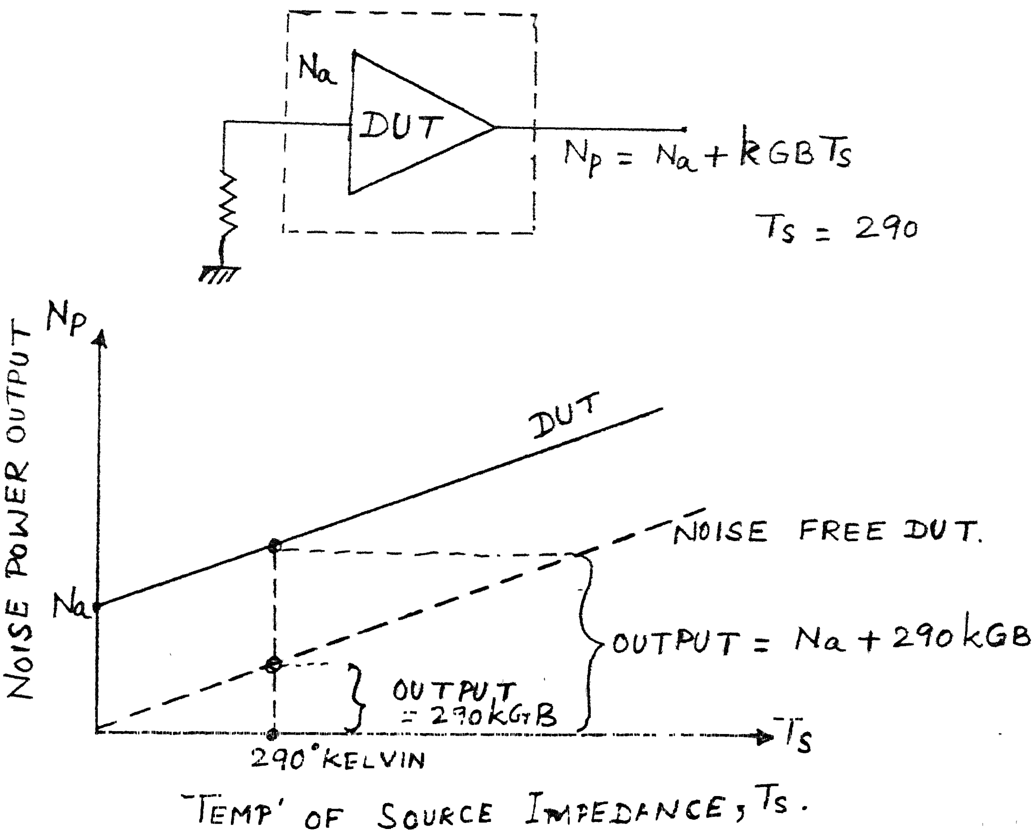


Fig. 3.1: Beamwidth of an Antenna



3.3 NOISE FIGURE:

Noise Figure of a receiver or amplifier is a measure of the deterioration of Signal to Noise ratio (SNR) caused by the amplifying device. Specifically, Noise Figure is the SNR at the input of the device divided by the SNR at the output of the device, expressed in dB [9]. If the device under consideration were noiseless, the SNR would be unchanged by the device and the Noise Figure would be zero dB - an ideal case. But however, all electronic devices add noise to a signal as the signal passes through, reducing the SNR. If the SNR at the output of the device is half the SNR at the input, noise figure is 3 dB. A mathematical expression for noise figure is

$$NF = 10 \log \frac{Si/Ni}{So/No}$$

$$= 10 \log_{10}(Si/Ni) - 10 \log_{10}(So/No) \qquad (3.3)$$

where,

NF	= Noise Figure in dB
(Si/Ni)	= Input Signal to Noise power ratio
(So/No)	= Output Signal to Noise power ratio

Noise figure is sometimes referred to as a 'Figure of Merit' of a device or system, which is an accurate appraisal. The noise figure of a device is a measure of how the device handles its internal noise in order to produce an output that is as noise-free as possible. If the noise is dealt with effectively, it is a measure of merit of the device. Though noise is usually expressed in dB, it can be termed a Noise Temperature in degree Kelvin. A formula describes the relationship between Noise Figure and Noise Temperature.

$$\text{Noise Figure (in dB)} = 10 \log_{10}\left(1+ \frac{T_N}{290}\right) \qquad (3.4)$$

where T_N is the noise temperature in ^oK.

There are many different methods of measuring noise, such as the Twice Factor, Y-Factor, and Hot-Cold Noise Source processes. Though valid means of determining noise figures, they are time consuming and thus not used practically. The method most widely used in microwaves, is the 'Automatic Noise Figure measurement'. The basic theory of measurement is briefly described as follows.

Noise Figure may also be expressed as the ratio of total output noise power (at a source temperature of

290° Kelvin) compared to the output noise power if there were no noise added by the device under test (DUT), that is a noise free DUT. Consider the representation of noise power at the output of a DUT vs. the temperature of the source impedance at the DUT input.

$$N_p = N_a + kGB\ T_s \qquad (3.5)$$

where,

N_a is the noise added by the DUT

k is the Boltzmann's constant

G is the Gain of the DUT

B is the Bandwidth in Hertz

and T_s is the temperature of the source termination in Kelvins.

Thermal agitation energy of the source impedance causes movement of the free charge in that impedance. Energy of the moving charge that occurs within the bandwidth of the DUT masquerades as input signal, gets processed by the DUT, and contributes to power output. At absolute zero, there is no thermal energy transferred from the source impedance and the only power at the output is noise added by the DUT, N_a. As the source temperature increases, the power output increases in accordance with the gain-bandwidth product and with

Boltzmann's constant (which can be thought of as a conversion factor between two expressions for energy - Kelvin temperature and joules). Noise Figure is concerned with the behavior of the DUT compared to noise free DUT for a source temperature of $290^{o}K$ as shown in Fig. 3.2. Noise figure is often expressed in dB by

$$N.F.\ (dB) = 10 \log_{10}(F) \tag{3.6}$$

where,

$$F = \frac{\text{Output of DUT}}{\text{Output of Noise-free DUT}}$$

$$= \frac{N_a + 290\ kGB}{290\ kGB} \tag{3.7}$$

Noise Figure meter measures noise figure by comparing the output of the DUT when the noise source is ON (P_o), to the output of the DUT when the noise source is OFF (N_o). The comparison is made by keeping P_o constant with automatic gain control and metering N_o. The details of noise source and the measurement made on a Low Noise amplifier are given in the following chapter.

CHAPTER 4

SYSTEM PARAMETER MEASUREMENTS

4.1 GENERAL:

Power, frequency, transmission, reflection (Impedance) and Noise are the five basic microwave measurements.Network analyzer is primarily concerned with frequency, transmission and reflection measurements. Noise parameter of a device can be estimated using a Spectrum Analyzer or a Noise Figure-Meter. Impedance and Sidelobe level measurements on the antenna unit and the measurementents on a Low Noise Amplifier are briefly described here. Also a typical facility that can be gradually built up to make the microwave measurements fully modern and automatic is described. The test and evaluation on a Mixer preamplifier unit taken in such a modern facility is also included at the end.

4.2 MEASUREMENTS ON ANTENNA:

Measurement of Impedance: Impedance (or Return loss) of the antenna array unit is measured using a Microwave Network Analyser. The measurement set up is shown in Fig. 4.1. The Network analyser system consists of the following:

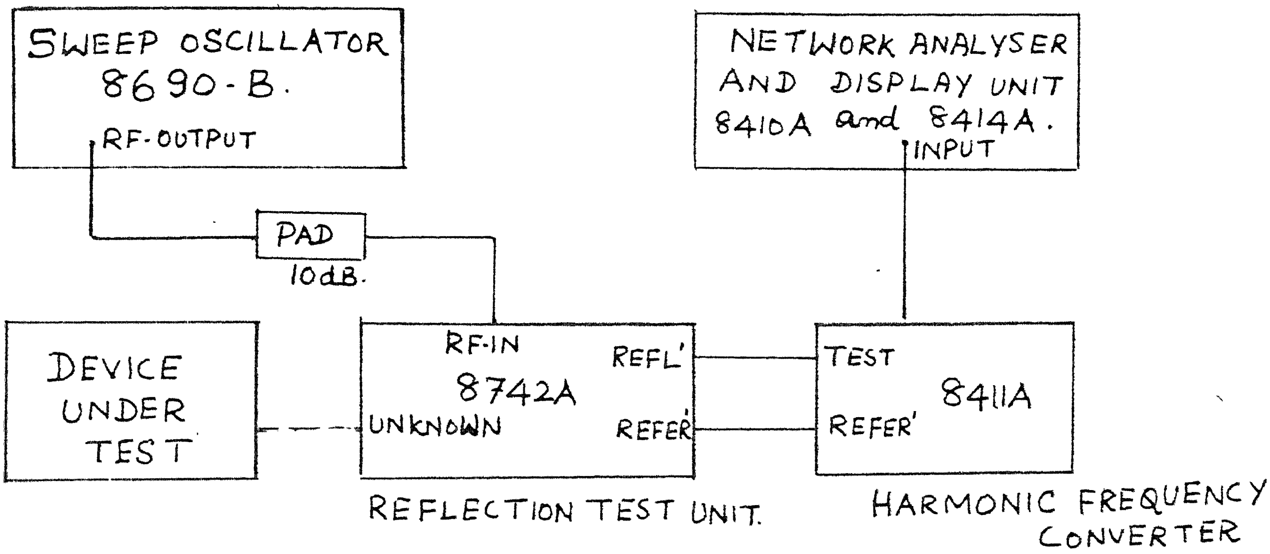


Fig. 4.1: Impedance Measurement - Setup

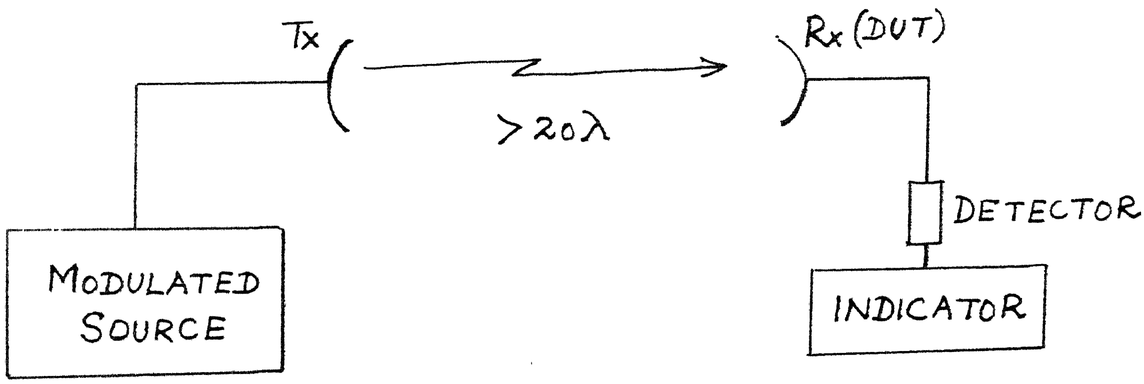


Fig. 4.3: Sidelobe level measurement - set up

a) Source - 8690B Sweep Oscillator

b) Signal Separation device - 8742A Reflection Test Unit

c) Analyzer and display - 8411A Harmonic Frequency, converter, 8410A Analyzer and 8414A display unit.

The source provides the 'stimulus' or incident RF signal for the DUT. Since the measurements are to be made over some frequency span, the stimulus normally is an electronically tuned source. The test device can respond to the stimulus in three ways: it can transmit, reflect or absorbe the incident signal. A typical test device will do all the three.

The signal separation device is required to separate the reflected from the incident signal. Reference and reflected signals are detected and analysed and then displayed. The complete details of the measuring equipments are available in the operating and service manuals [9]. Standard Smit chart overlay is used (instead of Return loss) to get the impedance values directly from the polar display unit.

Measurement Procedure:

1. The Measurement set up is powered on
2. A coaxial short is connected to the reflectometer unknown port.

3. Network Analyser is phase locked to the desired frequency - source output is adjusted to get the meter deflection in the 'operate' range.

4. The dot on the polar display is brought to the centre by pressing the 'BEAM-CTR' push button and adjusting 'HORIZ' and 'VERT' position controls.

5. Equal, Reference and test channel electrical lengths are obtained by adjusting the line stretcher (of the reflection test unit) to collapse the trace to a dot or smallest cluster.

6. Phase vernier, Test channel gain and Amplitude vernier controls of the Network analyzer are adjusted to place the dot for a reference indication $K = 1\angle 180^\circ$ (Reflectometer shorted at unknown port).

7. The short is removed and a standard 50 termination is connected. The dot should come to the centre of the graticule.

8. The termination is removed and the array is connected. The impedance is read using smith chart overlay from the polar display. The single frequency measurement of impedance is repeated for different frequencies.

Then the array is fixed on to the reflector and positioned at the focal length. The impedance measurement is repeated for the antenna array unit. The results are tabulated in Table 5. Fig. 4.2 shows the plot on Smith chart for the array and antenna unit.

Table 5: Impedance Measurements (Z_o = 50)

Frequency in GHz	Array Only		Array and Reflector	
	Normalised Value	Impedance value Ohms	Normalised value	Impedance value Ohms
2.8	0.4+j0.15	20+j7.5	0.6+j0.6	30+j30
2.9	0.8+j0.7	40+j35	1.2+j0.8	60+j40
3.0	1.2+j0.8	60+j40	1.3+j0.6	65+j30
3.05	0.8+j0.6	40+j30	0.7+j0.1	35+j5
3.10	1-j0.05	50-j2.5	1.05-j0.05	52.5-j2.5
3.2	0.75+j0.1	37.5+j5	1.2-j0.2	60-j10
3.3	1.2+j0.9	60+j45	0.65+j0.1	32.5+j5
3.4	1.4-j0.6	70-j30	1.0+j0.75	50+j37.5
3.5	0.75-j0.15	37.5-j7.5	0.95-j0.8	47.5+j40

IMPEDANCE OR ADMITTANCE COORDINATES

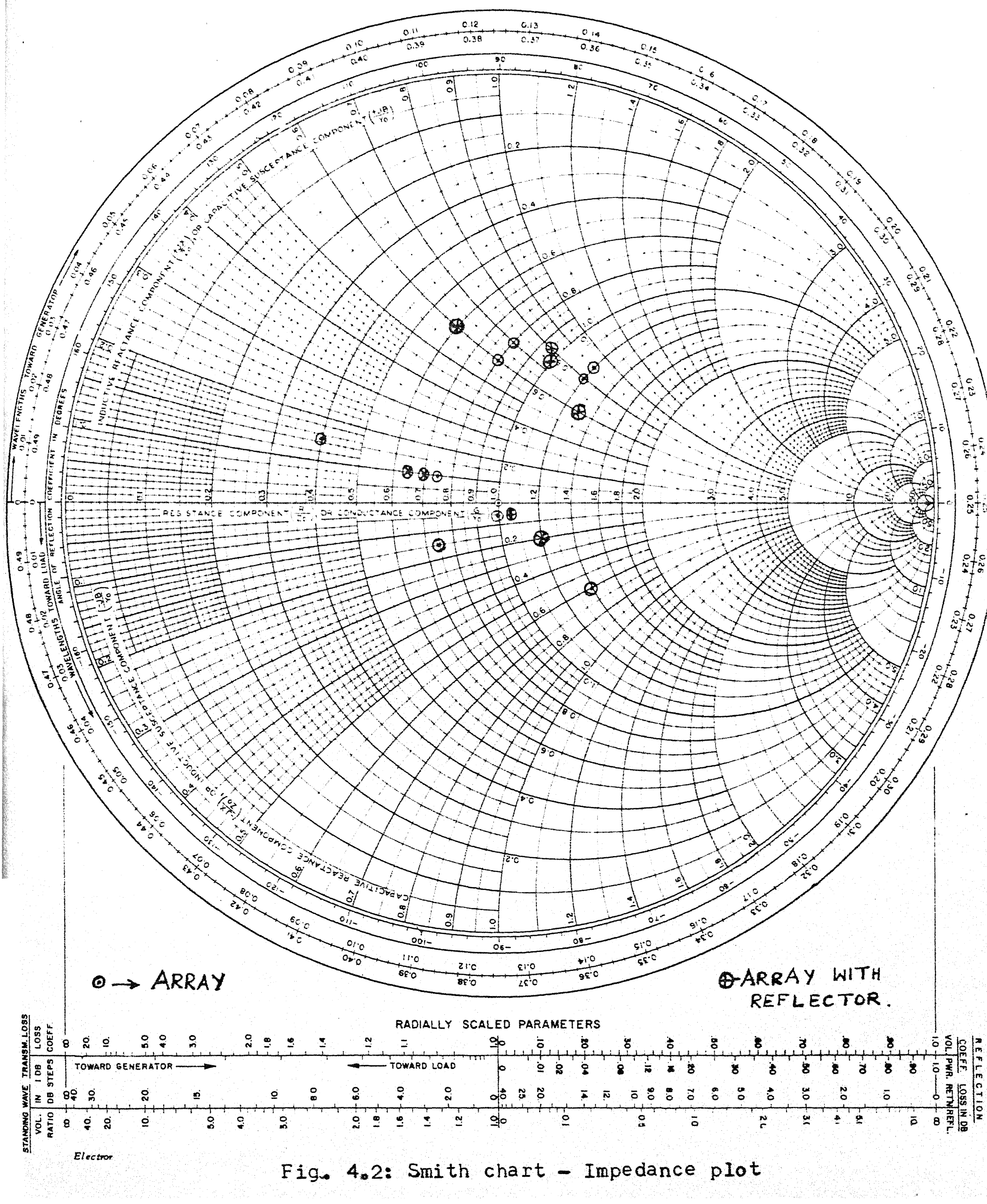


Fig. 4.2: Smith chart - Impedance plot

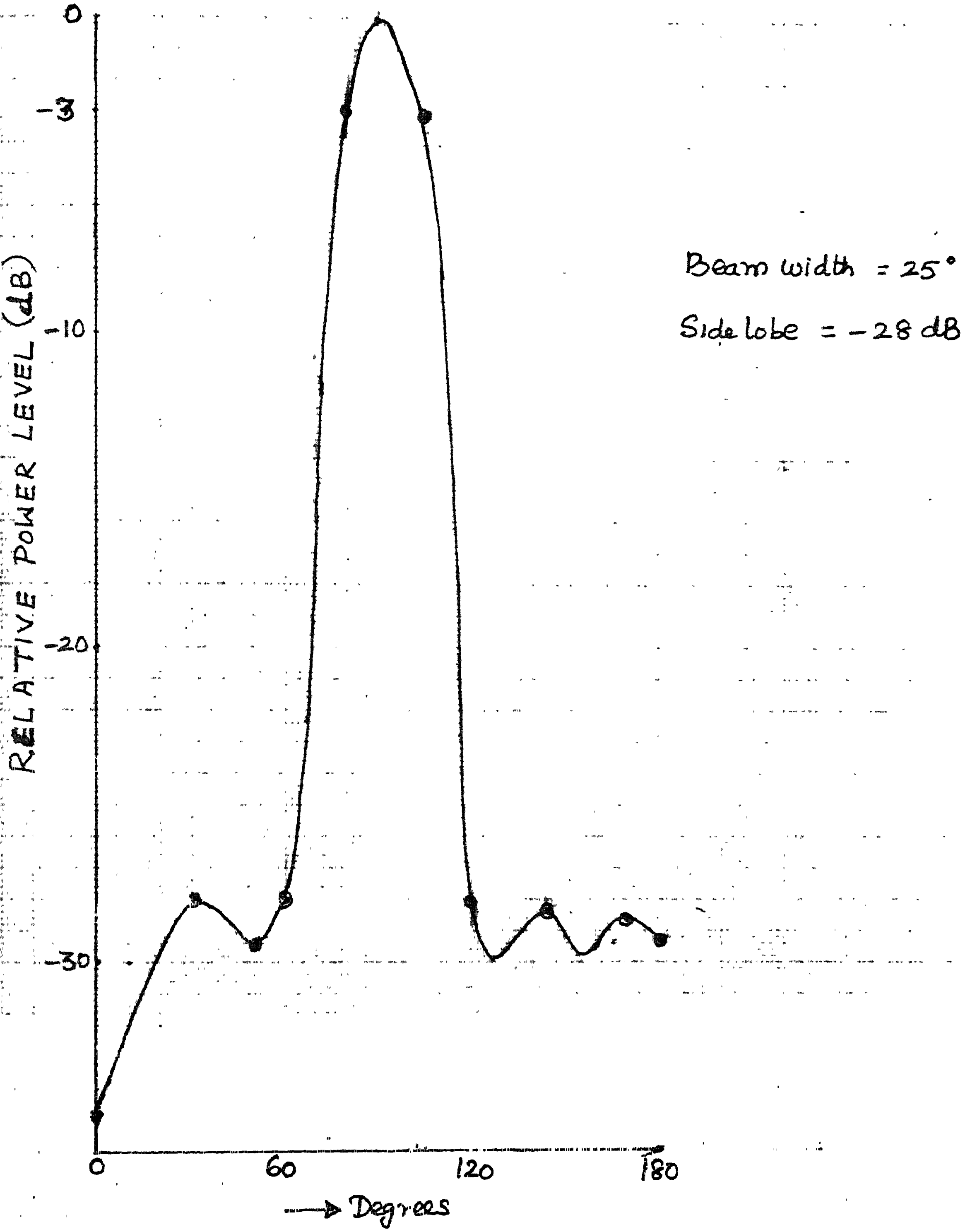


Fig. 4.4 Sidelobe-level

Measurement of Sidelobe level:

Fig. 4.3 shows the typical measurement set up used for the measurement of sidelobe level of the antenna. Basically the set up is meant for gain measurement. In this case the antenna under test is used as a receiving antenna. A microwave oscillator is used as a source and a parabolic dish is used as a transmitting antenna. The power level and frequency are adjusted to get the desired output indication on the SWR meter connected to the receiving antenna - tuned to its operating frequency. The relative power levels are noted - for different angles to obtain the radiation pattern. Fig. 4.4 shows the radiation pattern of the antenna. The sidelobes are 28 db below the level of the main lobe, and the half power beamwidth of the antenna is 25 degrees (i.e.) the angle between the 3 dB points on the mainlobe.

4.3 MEASUREMENTS ON LOW NOISE AMPLIFIER:

A Gallium Arsenide FET-low noise amplifier can be used as a receiver front end. The gain and Noise Figure parameter of the amplifier has been carried out as a part of receiver system.

Gain:

The measurement set up consists of a source 8690B and a power meter 435A with a sensor. The connections are made

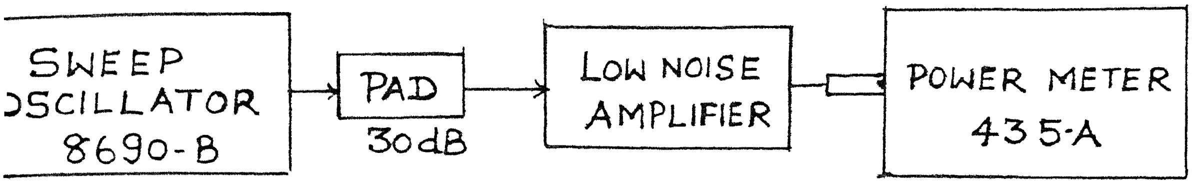


Fig. 4.5: Gain Measurement of an Amplifier

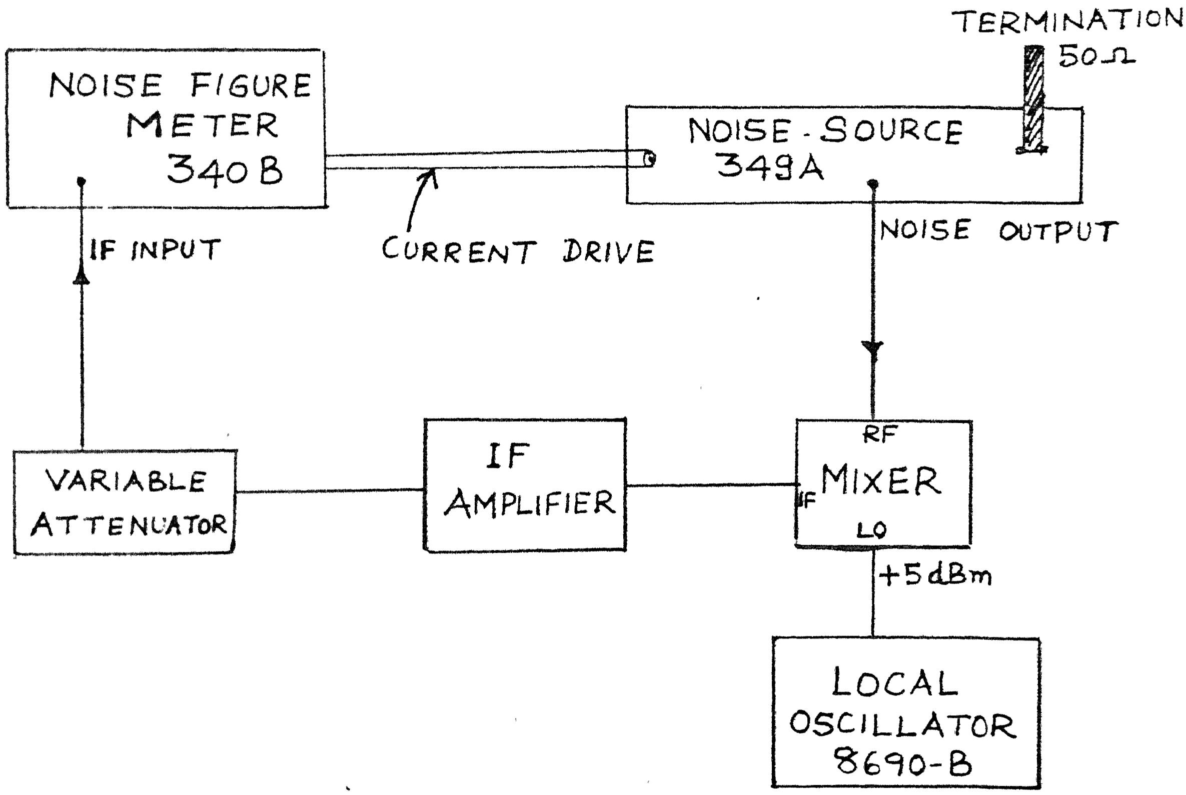


Fig. 4.7: Noise Figure Measurement set up

as shown in Fig. 4.5. The frequency response measurements are carried out for the frequency range of 1.5 to 3.5 GHz. The Table 7 shows the frequency vs. gain, and Fig. 4.6 shows the frequency response characteristic of the Low Noise Amplifier. The measurements are carried out for an input level of -40 dBm.

Noise Figure:

The Noise Figure Measurement set up is shown in Fig. 4.7. Model HP 340B Noise Figure Meter with the Model HP349A Noise Source, automatically measures and continuously displays the Noise Figure of the receiver or amplifier to which it is attached.

The noise source is an ARGON Discharge tube, provides approximately 15.7 dB excess noise, operating between 400 and 4000 MHz. The noise source is connected to the Noise figure meter and the source current adjusted using the current control and the meter provided on the Noise Figure Meter. The source is then ready for operation. The noise source provides a known excess noise power throughout its spectrum. The output of the noise source is fed to the DUT and the noise source is alternately turned 'ON' and 'OFF' by means of a square wave modulating voltage, applied to the Noise Figure Meter. The

Table 7: GaAs FET - Low Noise Amplifier
Frequency Response

Frequency (GHz)	Gain (dB)
1.5	18.0
1.7	18.8
1.9	19.5
2.0	21.5
2.1	21.7
2.2	22.8
2.3	22.3
2.4	22.5
2.5	22.5
2.6	21.0
2.7	22.5
2.8	22.2
2.9	20.55
3.0	19.00
3.1	17.50
3.2	16.00
3.3	15.30
3.4	14.50
3.5	13.50

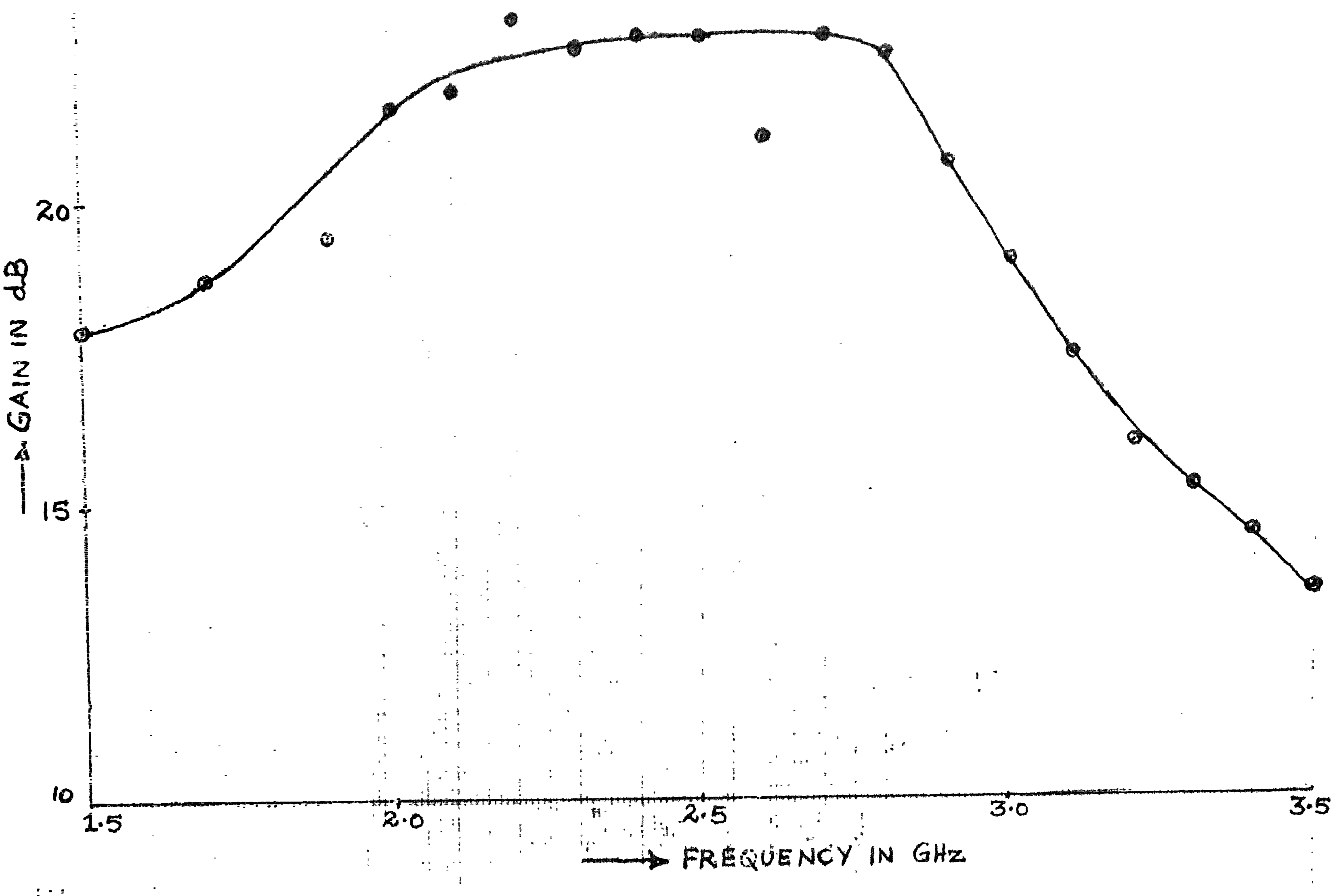


Fig. 4.6: Frequency Response of an Amplifier

Noise Figure of the DUT is measured by comparing the noise output of the DUT when the noise source is 'ON' to the noise output of the DUT when the noise source is 'OFF'. The noise figure meter makes this measurement automatically.

The mixer and IF amplifier as stated in the figure are used, since the output frequency of the DUT exceeds the input capability of the noise figure meter. The automatic noise figure meter has a tuned input; that is it can not operate at just any frequency. The 340B has got 30/60 MHz input frequency selection. Hence the microwave spectrum has to undergo some sort of frequency conversion - the mixer and its associated IF amplifier, provides that change. A attenuator has been provided to control the IF input and also to correct for any impedance mismatch.

NF Measurement:

The measurement set up is switched ON. AUTO mode is selected from the rear panel setting AUTO/MANUAL. Local oscillator power is set for +5 dBm as input to the mixer. The level of signal into the noise figure meter should be between -60 and -10 dBm and the gain is adjusted by means of the variable attenuator. The measurement procedure is a two steps process to display Noise Figure.

Adjust of Tube Current:

a) Meter Function Switch is set to 2 MA
b) Noise Source Switch is set to GAS Tube (MA x 100).
c) Current control is adjusted to 1.5 mA on meter. This provides 150 mA current to the Noise Source.

Measurement:

a) The input (IF) switch is selected to the required IF frequency.
b) The meter function switch is set to zero and ∞ and screw driver adjustment is made for initial calibration.
c) The meter function switch is set to Noise Figure and the Noise Figure of the DUT is read directly in dB on Gas Tube scale.

The measurement procedure is repeated for different LO frequencies, and the results are tabulated in Table 8.

Accuracy Improvement:

The accuracy of the 340B in measuring noise figure of 10 dB or less in the microwave frequency bands is ±1 dB. The accuracy can be improved to ±0.5 dB by the following technique. The excess noise output of 15.2 dB is reduced by

Table 8: Noise Figure Measurement on GaAs FET Low Noise Amplifier.

Local oscillator power = +5 dBm

Local Oscillator Frequency - GHz	Noise Figure - dB (IF = 30 MHz)	Noise Figure dB IF = 60 MHz
2.5	4.6	5.2
2.6	4.6	5.2
2.7	4.6	5.2
2.8	4.6	6.3
2.9	4.7	7.0
3.0	4.8	8.9
3.1	5.5	11.0
3.2	6.5	15.0
3.3	8.0	18.0
3.4	11.5	22.5
3.5	14.0	25.0

Table 8: Noise Figure Measurement on GaAs FET Low Noise Amplifier.

Local oscillator power = +5 dBm

Local Oscillator Frequency - GHz	Noise Figure - dB (IF = 30 MHz)	Noise Figure dB IF = 60 MHz
2.5	4.6	5.2
2.6	4.6	5.2
2.7	4.6	5.2
2.8	4.6	6.3
2.9	4.7	7.0
3.0	4.8	8.9
3.1	5.5	11.0
3.2	6.5	15.0
3.3	8.0	18.0
3.4	11.5	22.5
3.5	14.0	25.0

10 dB by connecting a 10 dB pad between the noise output and the DUT. Hence the excess noise applied to the DUT is 5.2 dB and the Noise figure is read directly on the Diode Scale (instead of gas tube scale) providing ± 0.5 dB accuracy.

Sources of Error:

Noise figure is a relative measurement based on power available from a termination (input resistor) at a particular temperature 290°K. Several factors - sources of error - can cause a difference between measured and actual noise figure. Most important of these factors are

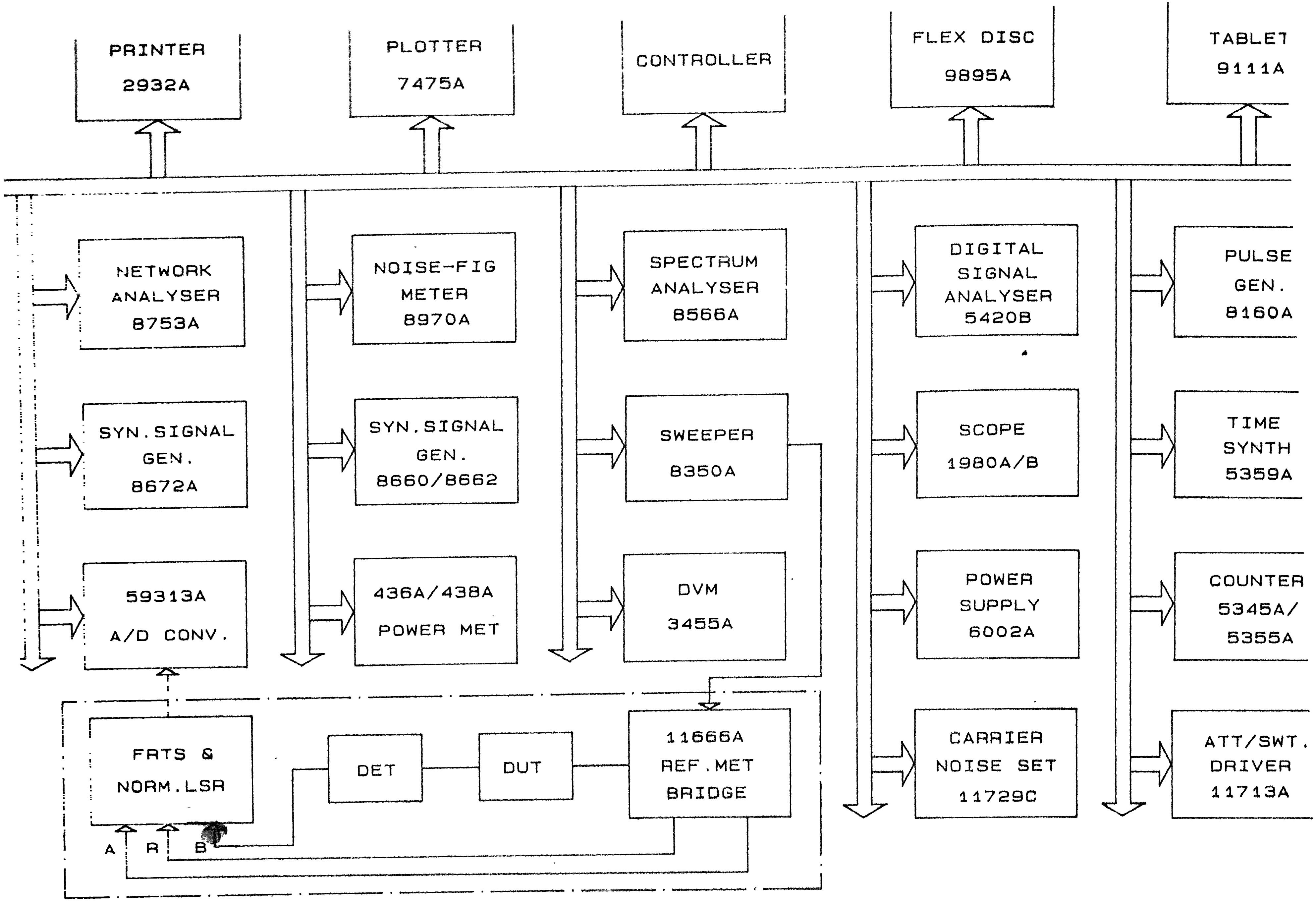
1) Coupling and transmission line errors
2) Ambient or termination temperature different from 290°K
3) Device (Receiver) mismatch
4) Noise source mismatch

Coupling and transmission line errors are due to insertion loss under Hot and Cold condition of the noise source. This error is less than 0.25 dB when using HP 349A noise source. Error correction for temperature difference and mismatches are available as standard graphs [9].

4.4 AUTOMATED MICROWAVE MEASUREMENT FACILITY:

During the time of measurement, the difficulty has arisen for the connection of appropriate instrumentation and setting up of the stimulus instruments for measurement and interpretation of data. The necessity has been felt for setting up of a 'Modern and Efficient Facility for Microwave measurements'. A typical set up shown in Fig. 4.8 is fully automatic which brings together in one centralized location several RF signal measurement capabilities.

The set up is configured around a 'controller' (Personal Computer) to work in the 'Hands off' mode. The controller is the heart of the set up (system) which regulates message traffic between instruments through the IEEE-488 Interface Bus. Every associating instrument performs atleast one of the roles of 'Talker', 'Listener', or 'Controller'. An instrument designated as 'Talker' (power meter) transmits data via the interface bus and 'Listener' (Plotter) receives data from other devices via the same interface bus. The controller designates the specific roles of each instrument and manages the bus, playing the role of human operator. The software packages are programmed, for different measurement situations, into the controller and are stored on tapes/disks for repeated use.


PRINTER
2932A
PLOTTER
7475A
CONTROLLER
FLEX DISC
9895A
TABLET
9111A
NETWORK ANALYSER 8753A
NOISE-FIG METER 8970A
SPECTRUM ANALYSER 8566A
DIGITAL SIGNAL ANALYSER 5420B
PULSE GEN. 8160A
SYN.SIGNAL GEN. 8672A
SYN.SIGNAL GEN. 8660/8662
SWEEPER 8350A
SCOPE 1980A/B
TIME SYNTH 5359A
59313A A/D CONV.
436A/438A POWER MET
DVM 3455A
POWER SUPPLY 6002A
COUNTER 5345A/ 5355A
FRTS & NORM.LSR
DET
DUT
11666A REF.MET BRIDGE
CARRIER NOISE SET 11729C
ATT/SWT. DRIVER 11713A
A
R
B

The IEEE-488 interface bus [9] provides an economical, yet extremely powerful means of communication between instruments in the measurement setup. The Interface Bus (IB) provides two way data flow over a single cable using standardised interface techniques. In the IB system a maximum number of 16 instruments including controller are connected in parallel. It is a non-synchronous, computer controlled measurement system where all the instruments used must possess IEEE-488 Interface Bus compatibility. The necessary active circuitry for this is contained in the test instruments, and the interconnecting cable is passive. The bus line system operates 16 parallel lines, 8 of these are used as Data Bus for transfer of measuring data, programming data and addresses. The Data Byte Transfer Control uses 3-lines and the remaining 5 lines are used for General Interface management messages.

The software-measurement programs are made easy by the use of 'programming codes'. The controller designates which instrument will be the talker and which the listener in each operation by using address codes. For example, the controller might designate itself as the talker and a source (Synthesizer) as the listener in order to instruct it to go to a certain frequency.

A simple configuration of measurement set up is shown in Fig. 4.9. A sample program shown below is all that needed to instruct the synthesizer to go to a certain frequency at certain power level and to instruct a power meter to take a reading and send it to the controller. The reading is then placed in the controller memory register 'A'. Frequency response data of the synthesizer is obtained based on this program.

Sample Program:

Line θ :	wrt 715,	'P15000000J5'
	Next data will be sent from controller to synthesizer.	Synthesizer is now set to a frequency 15 GHz.
Line 1 :	wrt 720 ,	'9 + DT'
	Next data will be sent from controller to the power meter	Set the power meter for autoranging to make the measurement in dBm.
Line 2 :	red 720 ,	'A'
	Next data will be received by the controller from the power meter.	The measured value of power will be stored into the variable register 'A' of the controller.

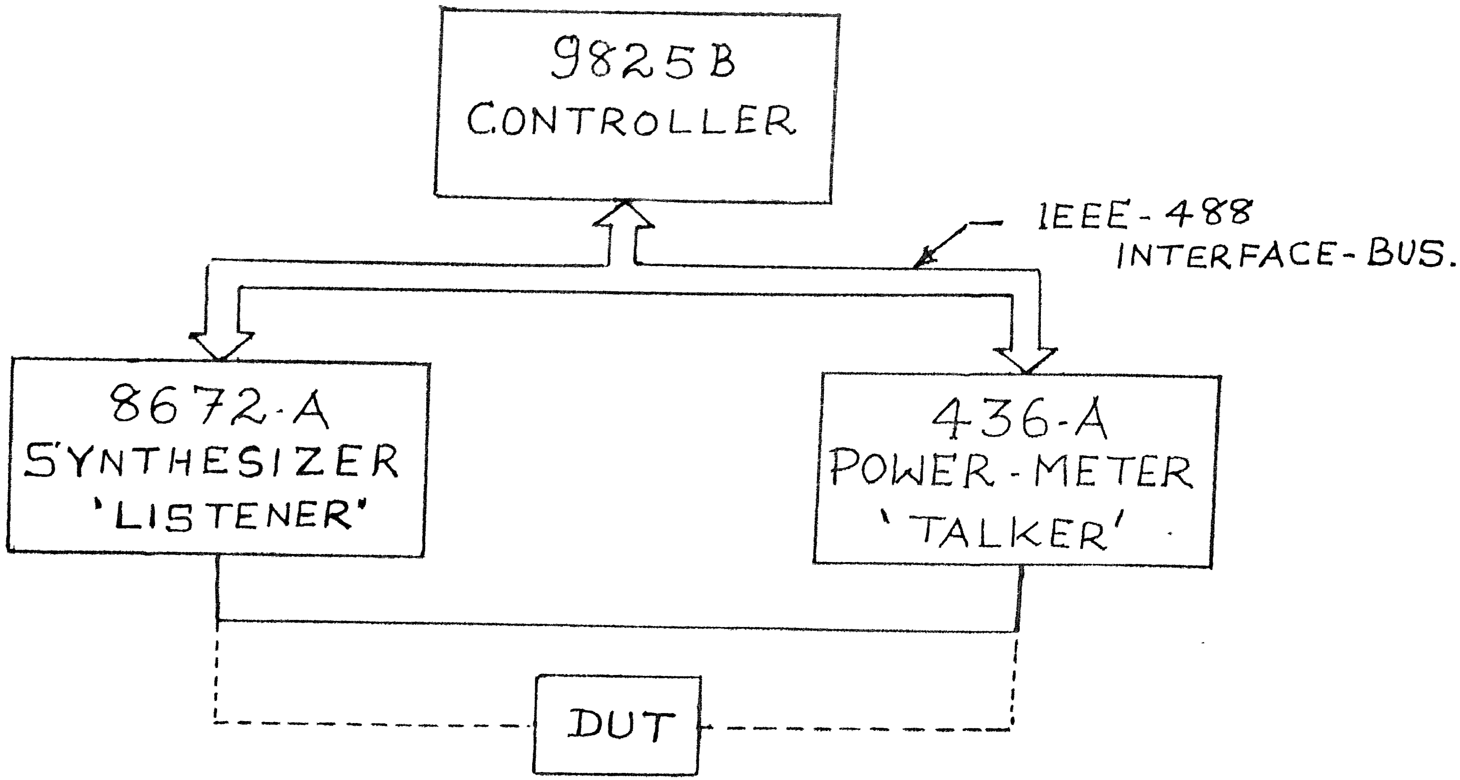


Fig. 4.9: A Simple Automatic Measurement set up

The above program can be modified to vary the frequency for its entire range at fixed intervals and the corresponding power is measured and stored. The stored data can be used to plot the frequency response characteristic of the synthesizer. The program can be further extended to find the insertion gain/loss of a device. The first set of reading will become reference data. Then the measurement is repeated with the DUT connected in between the synthesizer and the power meter. The difference between the measured data and the reference data gives the exact insertion gain/loss of the device at that frequency. These data are stored for different frequencies and the insertion gain/loss of the device is plotted.

Since the set up is automatic and controlled through software, it has a high speed of operation. The system caters to a very high degree of accuracy with minimum operator's interference and also it takes care of calibration and system error correction automatically. The typical set up shown in Fig. 4.8 covers a wide frequency range of 10 MHz to 20 GHz, adequate for the most of the microwave measurements.

4.5 MIXER PREAMPLIFIER EVALUATION:

Conversion gain, 1 dB compression point and bandwidth of a mixer preamplifier has been evaluated in a typical measurement set up as shown in Fig. 4.10. The complete program for the measurement is given in the Appendix A.

Gain:

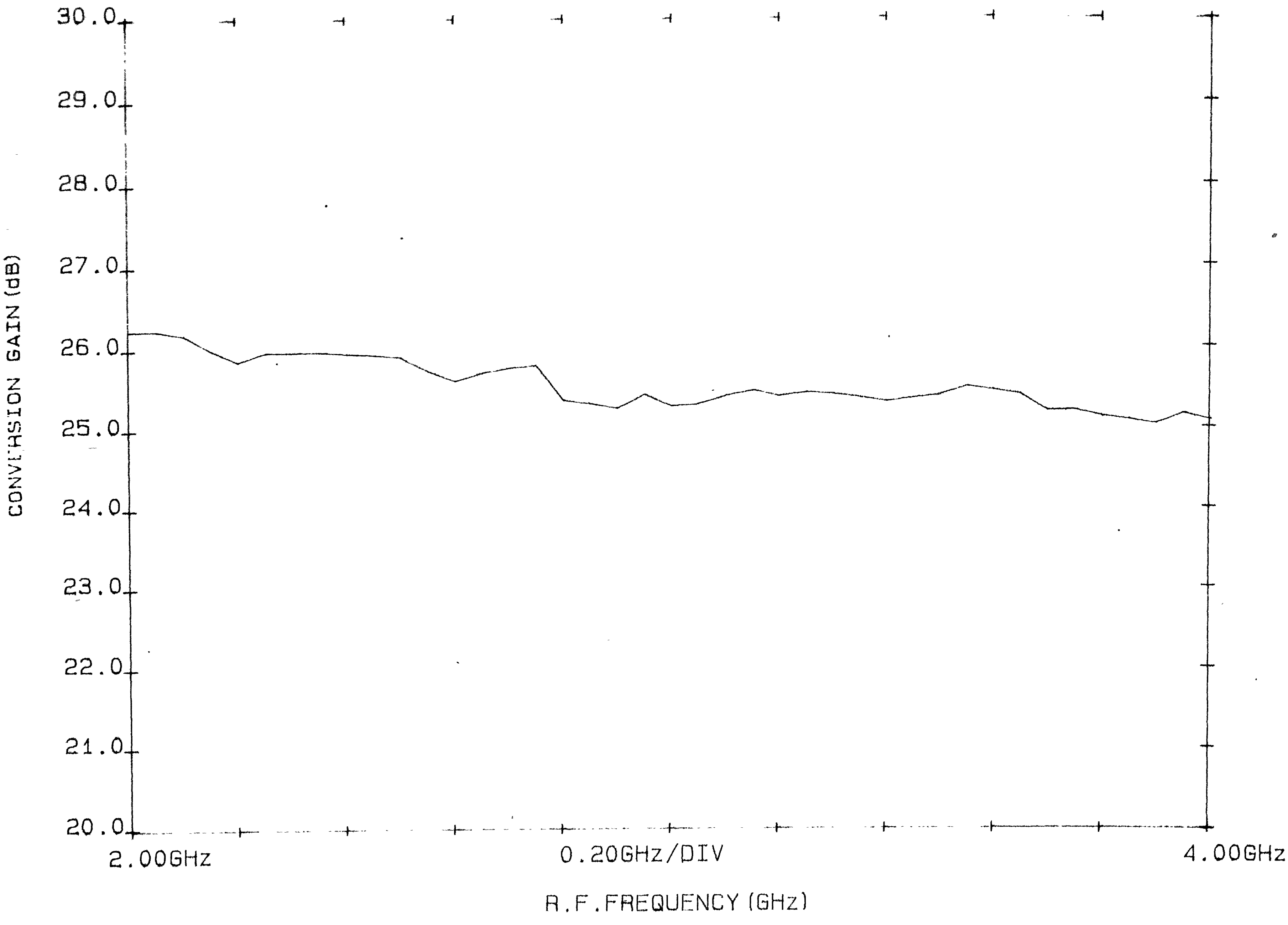
The mixer preamplifier has a built-in IF amplifier. The gain of the unit has been evaluated for the frequency range of 2 to 4 GHz with the RF power input of -40 dBm. The frequency response characteristic is shown in Fig. 4.11.

1 dB Compression Point:

1 dB compression point is that input level beyond which the linearity in the amplification is reduced. That is the level beyond which 1 dB increase in input level does not give 1 dB increase at the output. All the devices should be operated lower than this level as input to avoid intermodulation. Measurement has been carried out at the RF frequency of 3 GHz and the corresponding local oscillator frequency, by varying the input level from -30 dBm to 0 dBm. From Fig. 4.12 the 1 dB compression point can be located as -12 dBm.

IF Bandwidth:

The IF bandwidth of the mixer preamplifier is evaluated as follows. The RF frequency and input level is kept constant as 3 GHz at -40 dBm. The Local oscillator frequency is varied over the range (LO $\pm$ 50 MHz) in steps of 5 MHz. The frequency vs. gain plot Fig. 4.13 gives the IF bandwidth (3 dB) of about 70 MHz.



30.0
29.0
28.0
27.0
26.0
25.0
24.0
23.0
22.0
21.0
20.0
CONVERSION GAIN (dB)
2.00GHz
0.20GHz/DIV
4.00GHz
R.F.FREQUENCY (GHz)

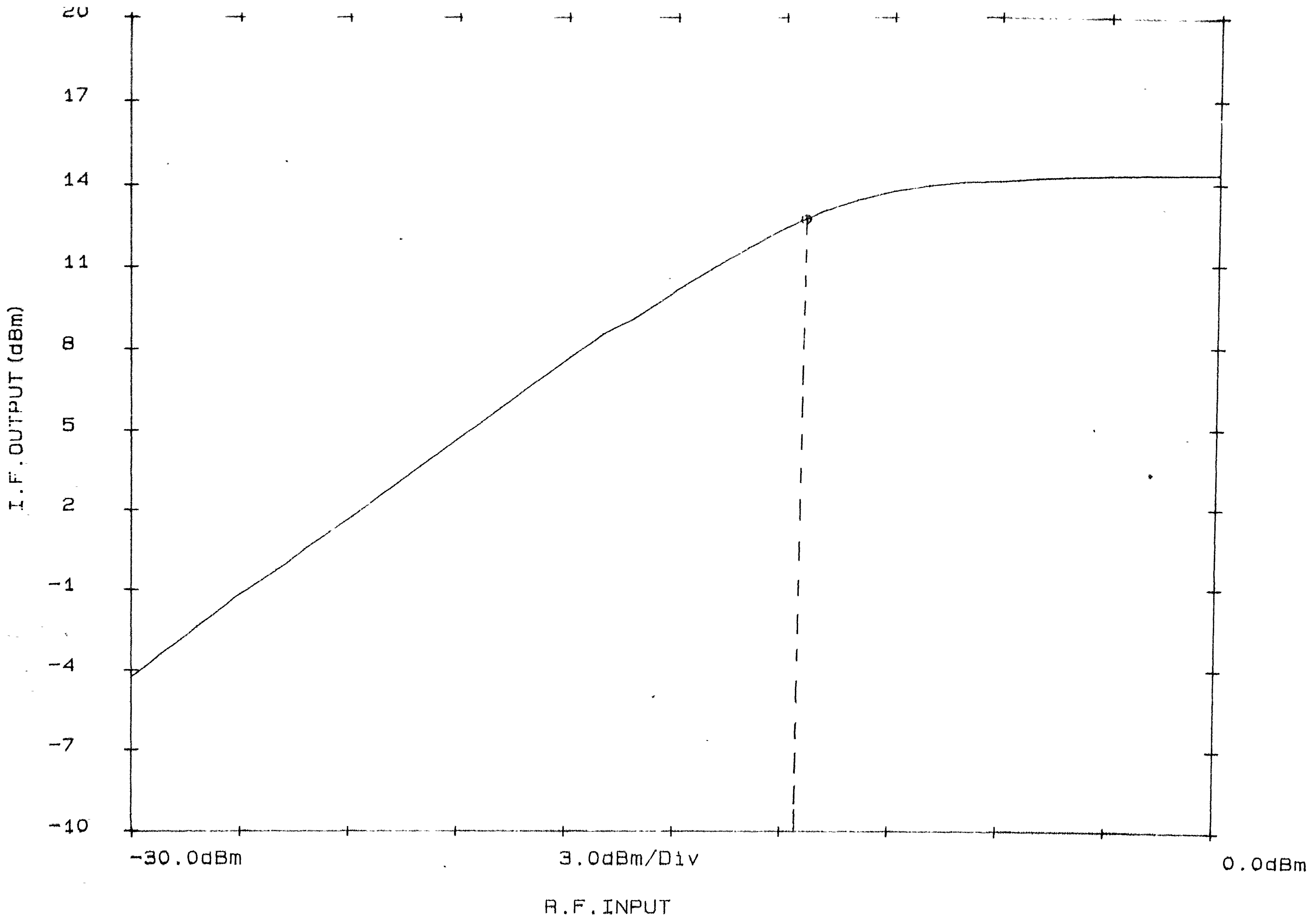
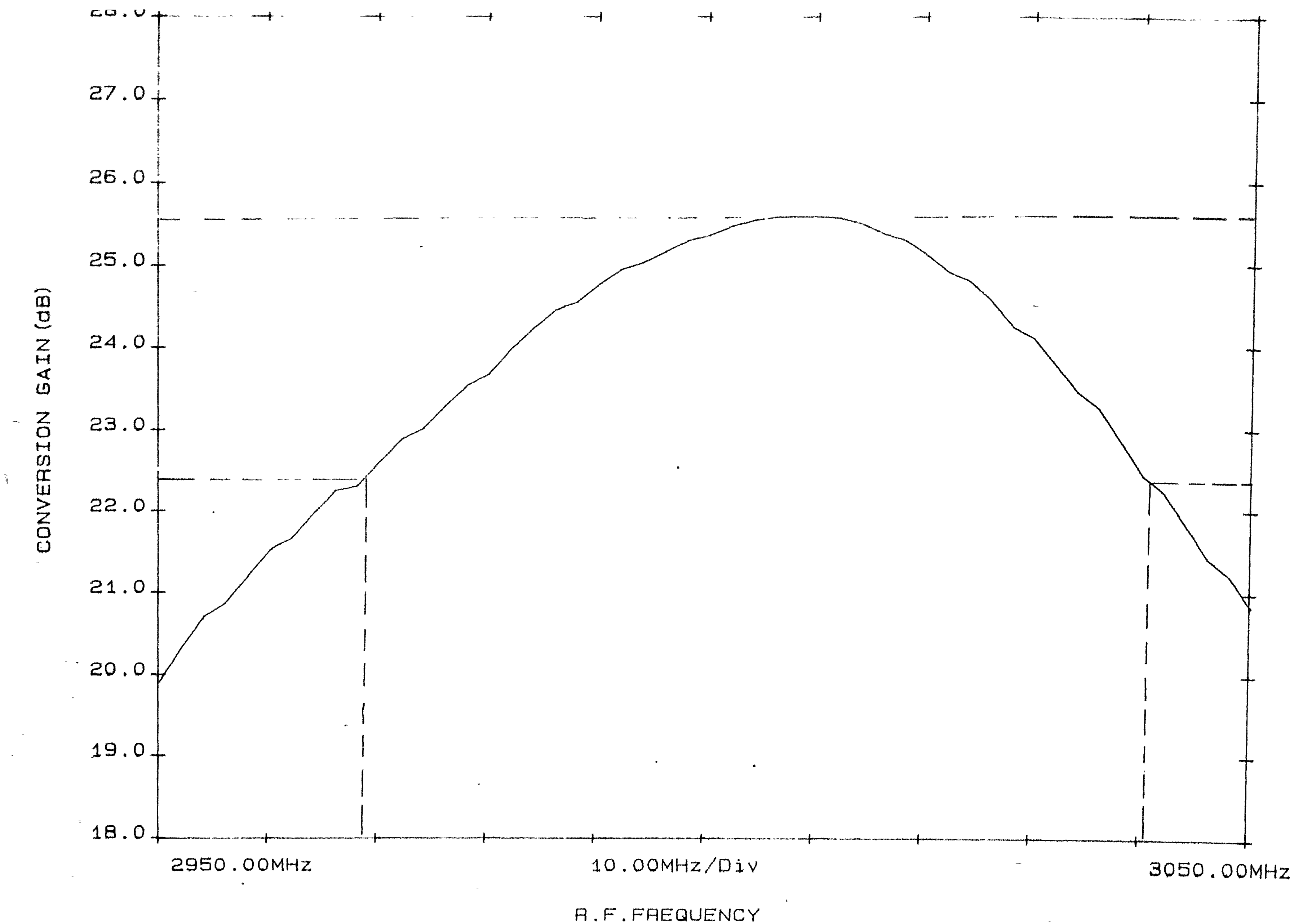


Fig. 4.12: MPA - 1 dB Compression Point



28.0
27.0
26.0
25.0
24.0
23.0
22.0
21.0
20.0
19.0
18.0
CONVERSION GAIN (dB)
2950.00MHz
10.00MHz/Div
3050.00MHz
R.F.FREQUENCY

CHAPTER 5

CONCLUSIONS

A Dolph-chebyshev array has been developed in a microstrip form on a RT/duroid polytetrafluorethylene substrate and tested with the small parabolic cylinder reflector designed and fabricated at S-band frequency. In addition to this development work, the microwave measurement activity has been revived. The Microwave Network Analyser and Noise Figure Measurement setups have been made operational for making measurements.

A down converter unit essential for Noise Figure Measurement set up has been developed using a Watkins - Johnson MIXER (LOIRF - 2.6 GHz, IF - DC to 1.5 GHz, LO power + 7 dBm) and IF Wideband amplifier using LM-733. Noise Figure Measurements have been carried out on a GaAs FET - Low Noise Amplifier. During the time of measurements, the necessity has been felt for a modern and efficient facility for microwave measurements. Hence a brief description of a typical Automatic Microwave Measurement facility is also included.

S-band antennas finds application in the reception of satellite signal. The design and fabrication techniques can be used for the development of larger (aperture area) diameter reflector and the array for a particular frequency of interest. A special augmented receiver, with a low noise front end amplifier and tuner, is needed to pick-up satellite signals which can be undertaken as a future development activity.

REFERENCES

1. William V. Tilston, 'On Evaluating the Performance of Communication Antennas', IEEE Communications Magazine, Sept. 1981.

2. T.C. Edwards, 'FOUNDATIONS FOR MICROSTRIP CIRCUIT DESIGN', John Wiley and Sons, New York, 1981.

3. G.S. Raju, 'Technical Talks - Antennas in P and T Use' - TRC Publications, New Delhi.

4. L.V. Blake, 'ANTENNAS', John Wiley and Sons, New York, 1966.

5. Henry Jasik, 'ANTENNA ENGINEERING HANDBOOK', McGraw Hill, New York, 1961.

6. C.L. Dolph, 'A current distribution for broad side arrays which optimizes the relationship between beamwidth and sidelobe level', Proc. IRE, 34, June 1946, pp. 335-348.

7. C. Das Gupta, 'Build an Integrated Dolph-Chebyshev-array', Microwaves, November, 1976, pp. 54-58.

8. Thomas A. Milligan, 'Modern Antenna Design', McGraw-Hill Book Company, New York, 1985.

9. Hewlett Packard Company - Operating and Service Manuals (a) 8410A, 8411A and 8414A, (b) 340B and 349A, (c) HPIB Interface.

10. Harlan Howe, 'Stripline Circuit Design', Artech House, U.S.A., 1974.

APPENDIX - A

```
"MIXER PREAMPLIFIER evaluation for Gain,Comp. pointand band width":
"USING 8350A WITH GRAPHICS(HIGH.FREQ)":
"PROG'S WITH GRAPHICS-TRK0-FILE10":
"Equip. Req. are  SWEEP OSC.SYNH. SIGNAL GEN.and POWER METER":
dim R[301],D[8],S$[32],A$[2],B$[2],C$[4],F$[32],P$[10]
cli 7:lcl 7:rem 7:clr 7
time 5000:on err "ERROR"
"SET THE SWEEPER START/STOP LIMITS":
2>L:18.6>U
"SETUP DATA ENTRY":
ent "I.F FREQ.(GHz)=?",D:if flg13:cfg 13:.16>D
"DUT MEASUREMENT":
"NEXT":
ent "Device Label",S$
beep:dsp "Which Measurement";wait 1000
beep:ent "Freq vs Gain(Y/N)",B$:if flg13:cfg 13:jmp 0
if cap(B$)="Y";"GAIN">C$:gto "GAIN"
ent "Comp.Pt.Meas.(Y/N)",B$:if flg13:cfg 13:jmp 0
if cap(B$)="Y";"COMP">C$:gto "COMP"
ent "Bandwidth Meas.(Y/N)",B$:if flg13:cfg 13:jmp 0
if cap(B$)="Y";"BAND">C$:gto "BAND"
gto "NEXT"
"GAIN":dsp "Connect DUT":stp
ent "Start Freq.(GHz)=?",A:if A<L or A>U-D:beep:gto +0
ent "Stop Freq.(GHz)=?",B:if B<L or B>U-D:beep:gto +0
ent "Freq Step Size(GHz)=?",C
(B-A)/C+1>P:if P>=1 and P<=200:gto +2
beep:dsp "Too many frequencies";wait 750:gto -4
A>F
ent "R.F. Input power(dBm)=?",Z:abs(Z)+3>Z
for X=1 to P
cll 'OFSET'(F,Z):cll 'SFSET'(F):cll 'POWER'(Q)
Q+7.3>R[X]
F+C>F:next X
gto "OUTPUT"

"COMP":dsp "Connect DUT":stp
ent "RF Freq.(GHz)",F:if flg13:cfg 13;jmp 0
if F<L or F>U-D:beep:gto -1
cll 'SFSET'(F):fmt "P",f-9.3,"10":wrt 719,1000F
fmt :wait 50
ent "Min.RF Input power(dBm)",Z:abs(Z)+3>Z
ent "Max RF Input power(dBm)",Y:abs(Y)+3>Y
for X=Z to Y by -1
fmt "Q1K",fz2.0:wrt 719,X:wait 50:cll 'POWER'(Q)
Q>R[X]:next X
gto "OUTPUT"

"BAND":dsp "Connect DUT";stp
ent "RF Freq.(GHz)=?",F;if flg13:cfg 13;jmp 0
if F<L or F>U-D;beep:gto -1
```

3857

```
51: ent "R.F.Input Power(dBm)=?",Z;abs(Z)+3>Z
52: cll 'OFSET'(F,Z)
53: for X=-50 to 50 by 2
54: F+X/1000>E
55: cll 'SFSET'(E);cll 'POWER'(Q)
56: Q+Z-3>R[X+51];next X
57: gto "OUTPUT"
58:
59: "OUTPUT":cll 'PRESET'
60: beep;ent "List,Plot or Next(L,P,N)",A$;cap(A$)>A$
61: if A$="L";cll 'PRINT';gto "OUTPUT"
62: if A$="P";cll 'PLOT';gto "OUTPUT"
63: gto "NEXT"
64: end
65:
66: "PRESET":fmt ;wrt 719,"A3J0K;;O1KM0N6";ret
67:
68: "OFSET":
69: fmt ;fmt "P",fz9.3,"J0";wrt 719,1000*p1
70: fmt ;fmt "O1K",fz2.0;wrt 719,p2;wait 50;ret
71: "POWER":100>p0
72: fmt ;wrt 713,"9+DT";fmt 2b,x,e9;red 713,p2,p4,p1
73: if p2=90 and (abs(p1-p0)<.05 or p4>73);0>p2;ret
74: p1>p0;gto -2
75:
76: "SFSET":p1+D>p4
77: fmt 1,"FIOCW",f7.3,"GZSS",f7.3,"GHz"
78: wrt 725.1,p4,E;ret
79: wrt 725,"UP NT"
80: wait 50;ret
81:
82: "PRINT":fmt 4,3/,50x,c
83: fmt 5,c26,z;fmt 6,c26
84: fmt 7,4x,f12.3,4x,f6.2,z;fmt 8,4x,f12.3,4x,f6.2
85: wrt 701.4,C$
86: if C$="GAIN";cll 'PRINT1';ret
87: if C$="COMP";cll 'PRINT2';ret
88: if C$="BAND";cll 'PRINT3';ret
89: ret
90:
91: "PRINT1":
92: fmt 4,50x,c,/;wrt 701.4,"FREQUENCY VS GAIN"
93: "     Frequency        Gain">F$
94: for X=1 to 4;wrt 701.5,F$;next X;wrt 701.6,F$
95: "           (GHz)           (dB)">F$
96: for X=1 to 4;wrt 701.5,F$;next X;wrt 701.6,F$
97: 0>F
98: for X=1 to P
99: wrt 701+.1(7+(X-5int(X/5)=0)),F,R[X]
100: F+C>F;next X
*05966
```

```
101: ret
102:
103: "PRINT2":
104: fmt 4,50x,c,/;wrt 701.4,"COMPRESSION POINT"
105: "  Inputpower      IF O/P">F$
106: for X=1 to 4;wrt 701.5,F$:next X:wrt 701.6,F$
107: "       (dBm)            (dBm)">F$
108: for X=1 to 4;wrt 701.5,F$;next X:wrt 701.6,F$
109: for X=Z to Y by -1
110: wrt 701+.1(7+(X-5int(X/5)=0)),X,R[X]
111: next X
112: ret
113:
114: "PRINT3":
115: fmt 4,50x,c,/;wrt 701.4,"I.F. BANDWIDTH"
116: "  Frequency      Gain">F$
117: for X=1 to 4;wrt 701.5,F$:next X:wrt 701.6,F$
118: "          (GHz)         (dB)">F$
119: for X=1 to 4;wrt 701.5,F$:next X;wrt 701.6,F$
120: for X= 50 to 50 by 2
121: wrt 701+.1(7+(X-5int(X/5)=0)),F+X/1000,R[X+51]
122: next X
123: ret
124: "PLOT":
125: beep:dsp "PLOTTER READY?":stp
126: wtb 719,3,20,13,10,"FM:FN:EX:SN:RX:HM:"
127: scl -125,1125,-1100,100:lim -125,1125,-1100,100
128: ent "AXES PLOT REQUIRED(Y/N)",P$;if flg13:cfg 13:"Y">P$
129: if cap(P$)="N";if C$="GAIN";gto "DATAPLOT1"
130: if cap(P$)="N";if C$="COMP";gto "DATAPLOT2"
131: if cap(P$)="N";if C$="BAND";gto "DATAPLOT3"
132: "PPLOT":
133: lbl "  ";pen# 1
134: xax -1000,100,0,1000;yax 1000,100,-1000,0
135: xax 0, 100,1000,0;yax 0,-100,0,-1000
136: if C$="GAIN";cll 'PLOT1';ret
137: if C$="COMP";cll 'PLOT2';ret
138: if C$="BAND";cll 'PLOT3';ret
139:
140: "PLOT1":
141: csiz 1.5;fxd 1+(B-A<=2);plt 0,-1040,1:cplt -2.5,0:lbl A,"GHz"
142: plt 395,-1040,1;lbl .1(B-A),"GHz/DIV"
143: plt 1000,-1040,1;cplt -2.5,0:lbl B,"GHz"
144: plt 395,-1100,1;lbl "R.F.FREQUENCY(GHz)"
145: fxd 1
146: ent "Min.GAIN=",K:if flg13;cfg 13;10>K
147: ent "Max.GAIN=",J:if flg13;cfg 13:10>J
148: plt -100,-600,1:csiz 1.2,1.7,1,90;lbl "CONVERSION GAIN(dB)"
149: csiz
150: for I=0 to -1000 by -100
*19361
```

```
plt -75,I,1;lbl J-(K-J)I/1000;next I
plt 500,70,1:cplt -.5len(S$),0:lbl S$
plt 400,30,1;lbl "RF POWER LEVEL=",-Z+3,"dBm"
"DATAPLOT1":
scl -125,1125,-1100,100
pen# 2:fxd 2:A>F
for X=0 to P-1
plt X1000/(P-1),-(J-R[1+X])1000/(J-K)
F+C>F:next X
pen:pen# 0;ret
"PLOT2":
fxd 1:csiz 1.2.1.7.1,0:plt 0,-1040,1:lbl -Z+3,"dBm"
plt 385,-1040,1:lbl -(Y-Z)/10,"dBm/Div":plt 1000,-1040.1:lbl -Y+3,"dBm
fxd 0:plt 385,-1100.1:lbl "R.F.INPUT"
ent "Min I.F.Output(dBm)",K:if flg13:cfg 13:-25>K
ent "Max I.F.Output(dBm)",J:if flg13:cfg 13:15>J
for I=0 to -1000 by -100
plt -75,I,1:lbl J-(K-J)I/1000:next I
plt -100,-600,1:csiz 1.2.1.7.1 90:lbl "I.F.OUTPUT(dBm)"
csiz
plt 500,70,1:cplt -.5len(S$),0:lbl S$
plt 400,30,1:fxd 1:lbl "RF FREQUENCY=",F,"GHz"
"DATAPLOT2":
scl -125,1125,-1100,100
pen# 2:fxd 2
for X=Z to Y by -1
plt (Z-X)1000/(Z-Y),-(J-R[X])1000/(J-K)
next X
pen:pen# 0:ret

"PLOT3":csiz 1.2.1.7,1,0:plt 0,-1040.1:lbl 1000F-50,"MHz"
plt 385,-1040,1:lbl 10,"MHz/Div":plt 900.-1040,1:lbl 1000F+50,"MHz"
plt 385,-1100,1:lbl "R.F.FREQUENCY"
ent "Min.GAIN/LOSS=",K:if flg13:cfg 13:10>K
ent "Max.GAIN/LOSS=",J;if flg13:cfg 13;30>J
fxd 1
for I=0 to -1000 by -100
plt -75,I,1:lbl J-(K-J)I/1000:next I
plt -100,-650,1:csiz 1.2,1.7,1,90:lbl "CONVERSION GAIN(dB)"
csiz
plt 500,70,1;cplt -.5len(S$),0:lbl S$
plt 400,30,1:lbl "RF POWER LEVEL=",-Z+3,"dBm"
"DATAPLOT3":
pen# 2:fxd 2
scl -125,1125,-1100,100
for X=-50 to 50 by 2
plt (X+50)*10,-(J-R[X+51])1000/(J-K)
next X
pen:pen# 0;ret
"ERROR":
?
```

Date Slip

A 98015

This book is to be returned on the date last stamped.
